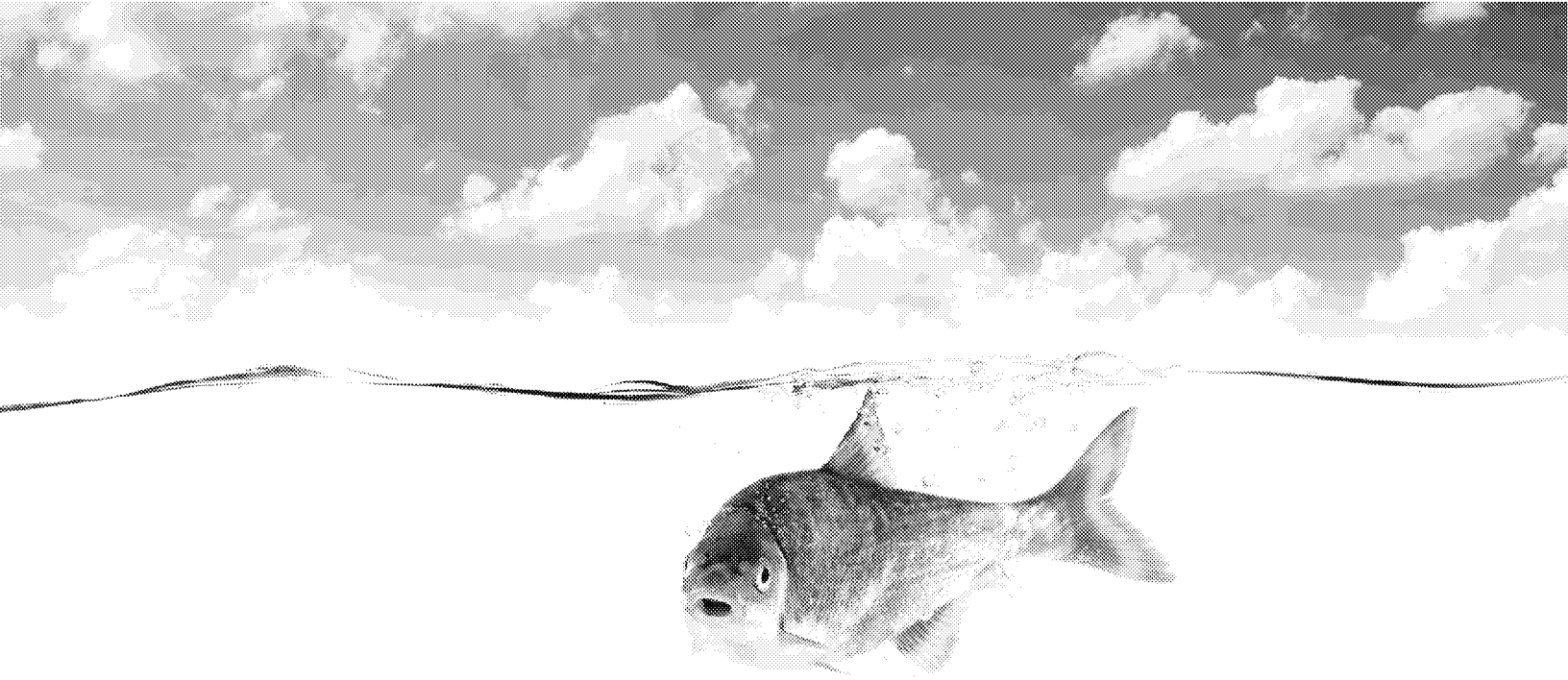

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A Stantec Consulting Company

Koocanusa Reservoir Monitoring Program Study Design, 2018 to 2020

Prepared for:
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April 2018

Koocanusa Reservoir Monitoring Program Study Design, 2018 to 2020

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ACRONYMS AND ABBREVIATIONS

ANOVA – Analysis of Variance

ANCOVA – Analysis of Covariance

AOP – Advanced Oxidation Process

AWTF – Active Water Treatment Facility

CALA – Canadian Association for Laboratory Accreditation Inc.

CES – Critical Effect Sizes

COC – Chain-of-custody

CPR – Cardiopulmonary Resuscitation

CRM – Certified Reference Materials

CTD – Profiler that Measures Conductivity, Temperature, and Depth

DO – Dissolved Oxygen

DQA – Data Quality Assessment

DQO – Data Quality Objective

DS – Downstream

EEM – Environmental Effects Monitoring

EHSC – Environment, Health, Safety, and Community

EMC – Environmental Monitoring Committee

ENV – British Columbia Ministry of Environment and Climate Change Strategy (formerly BCMOE)

EPWP – Environmental Protection Work Plan

EVWQP – Elk Valley Water Quality Plan

FLHA – Field Level Hazard Assessment

HR – High Resolution

ICP-MS – Inductively Coupled Plasma Mass Spectrometry

IS – Independent Scientist

KNC – Ktunaxa Nation Council

KS – Kolmogorov-Smirnov statistical test

LEL – Lowest Effect Level

LRL – Laboratory Reporting Limit

LLOQ – Lower Limit of Quantitation

MCT – Measure of Central Tendency

MDL – Method Detection Limit

MFWP – Montana Fish Wildlife, and Parks

MOD – Magnitude of Difference

MU – Management Unit

NMDS – Nonmetric Multidimensional Scaling Ordination

PAH – Polycyclic Aromatic Hydrocarbon

PEL – Probable Effect Level

QA/QC – Quality Assurance / Quality Control

RAEMP – Regional Aquatic Effects Monitoring Program

RPD – Relative Percent Difference

SD – Standard Deviation

SEL – Severe Effect Level

SOP – Standard Operating Procedures

SPO – Site Performance Objective

TEL – Threshold Effect Level

TOC – Total Organic Carbon

TSI – Trophic Status Index

US – Upstream

USACE – U.S. Army Corps of Engineers

USEPA – U.S. Environmental Protection Agency

UTM – Universal Transverse Mercator system

WHMIS – Workplace Hazardous Materials Information System

WLC – West Line Creek

WSQG – Working Sediment Quality Guidelines

YOY – Young-of-the-year

1 INTRODUCTION

1.1 Background

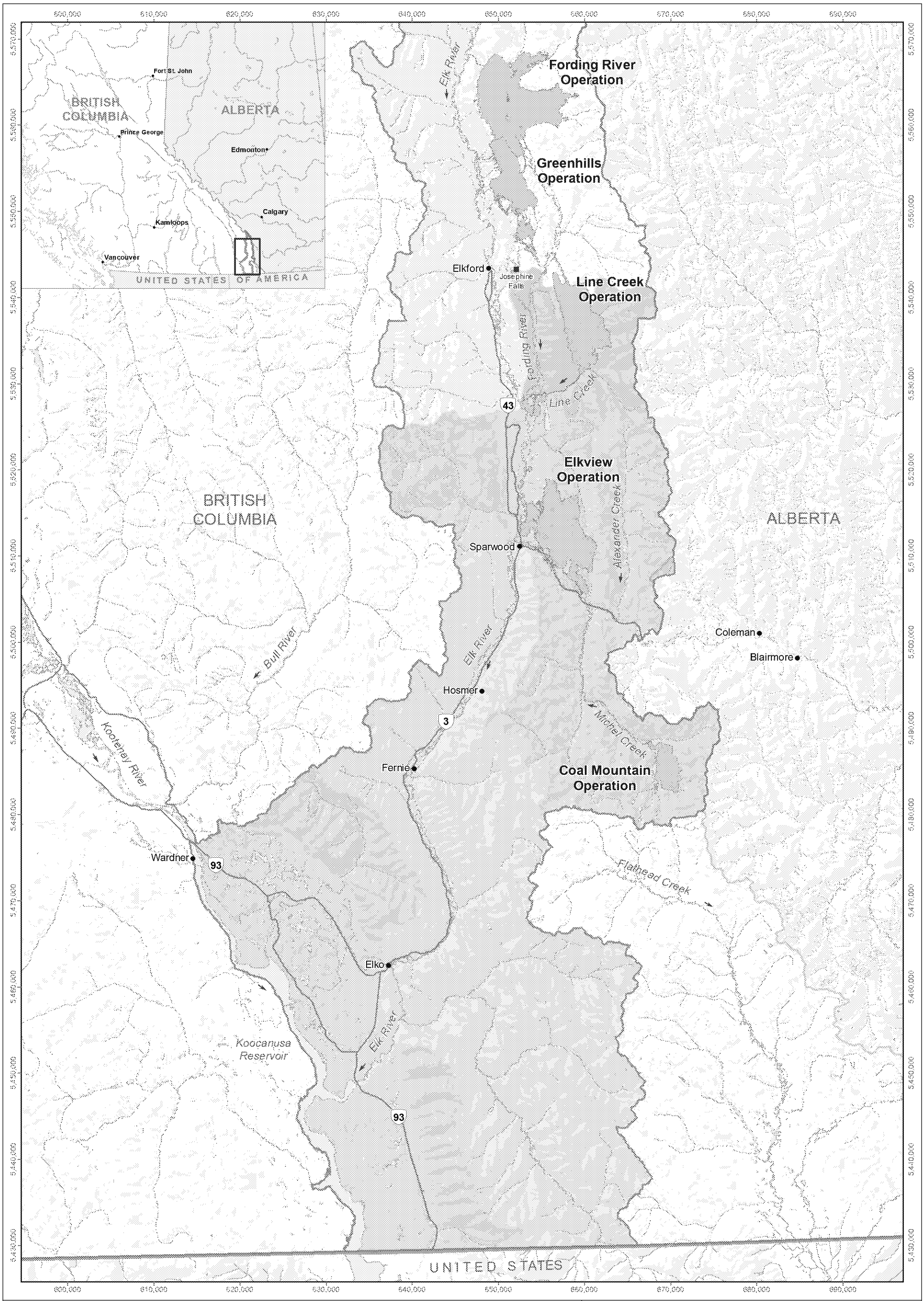
1.1.1 Study Area

Teck Coal Limited (Teck) owns and operates five metallurgical coal mines within the Elk River watershed in southeastern British Columbia (BC; Figure 1.1). The Elk River watershed is located in the southeastern corner of BC in the rugged terrain of the Front and Border Ranges of the Rocky Mountains, with peaks up to 3,300 metres (m) in the north and 2,200 m in the south. From its headwaters at Elk Lakes near the continental divide, the Elk River flows in a southwesterly direction and into Koocanusa Reservoir about 20 kilometres (km) upstream from the Canada/United States (U.S.) border (Swain 2007; Kennedy et al. 2000).

Koocanusa Reservoir was created when the Libby Dam (Montana) was constructed in 1972 to provide flood protection, hydroelectric power, and recreation benefits (Storm et al. 1982). The Libby Dam is operated by the United States Army Corps of Engineers (USACE) and reached full pool in June 1974 (Storm et al. 1982). At full pool, the reservoir is 155 km in length and straddles the border between Canada (about 68 km in length) and United States (87 km in length; Hamilton et al. 1990). The reservoir (at full pool) has a volume of 7.2 km^3, average surface area of 188 km^2, mean depth of 38 m, and maximum depth of 107 m (which occurs in Montana; the maximum depth at the border is about 46 m). Drawdown to minimum operational pool reduces the total length of the reservoir to 68 km, the volume to 1.1 km^3, and surface area to 59 km^2 (Woods and Falter 1982). At maximum drawdown, this equates to a reduction in reservoir volume of up to 85%, mean depth by 51%, surface area by 69% and total length by 53%, with the largest relative changes occurring in the Canadian portion of the reservoir (Hamilton et al. 1990).

Three Canadian rivers, the Kootenay (62% of mean annual inflow), Elk (26%), and Bull (11%), supply most of the reservoir's inflow and, therefore, exert a major influence on the limnology of Koocanusa Reservoir (Woods 1982; Hamilton et al. 1990). Water levels within Koocanusa Reservoir are generally lowest in March through May and highest in summer/early fall (Figure 1.2). Normal annual pool fluctuation is about 35 m and mean residence time is 0.55 years (range 0.14 to 0.73 years) (Storm et al. 1982; Woods and Falter 1982; Hamilton et al. 1990).

The Ktunaxa First Nations (KNC) has occupied lands adjacent to, and including, the Kootenay and Columbia Rivers and the Arrow Lakes of BC for more than 10,000 years (KNC 2005). Rivers and streams of the region provide culturally important sources of fish and plants. The



LEGEND

- Teck Coal Mine Operation
- Designated Area (Defined by Ministerial Order M113 and Permit 107517)
- MU-1
- MU-2
- MU-3
- MU-4
- MU-5
- MU-6

Location of Teck's Coal Mine Operations Relative to the Elk River Watershed and Koocanusa Reservoir

0 5 10 20
km

N
W E
S

Projection: North American Datum 1983 UTM Zone 11

Date: April 2018
Project 177202.0048

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Figure 1.1

Document Path: S:\Projects\177202\177202 0048 - Teck Koocanusa 2017\Mapping\Study Design\17-48 Fig 1.1 Teck Coal Limited Operation.mxd

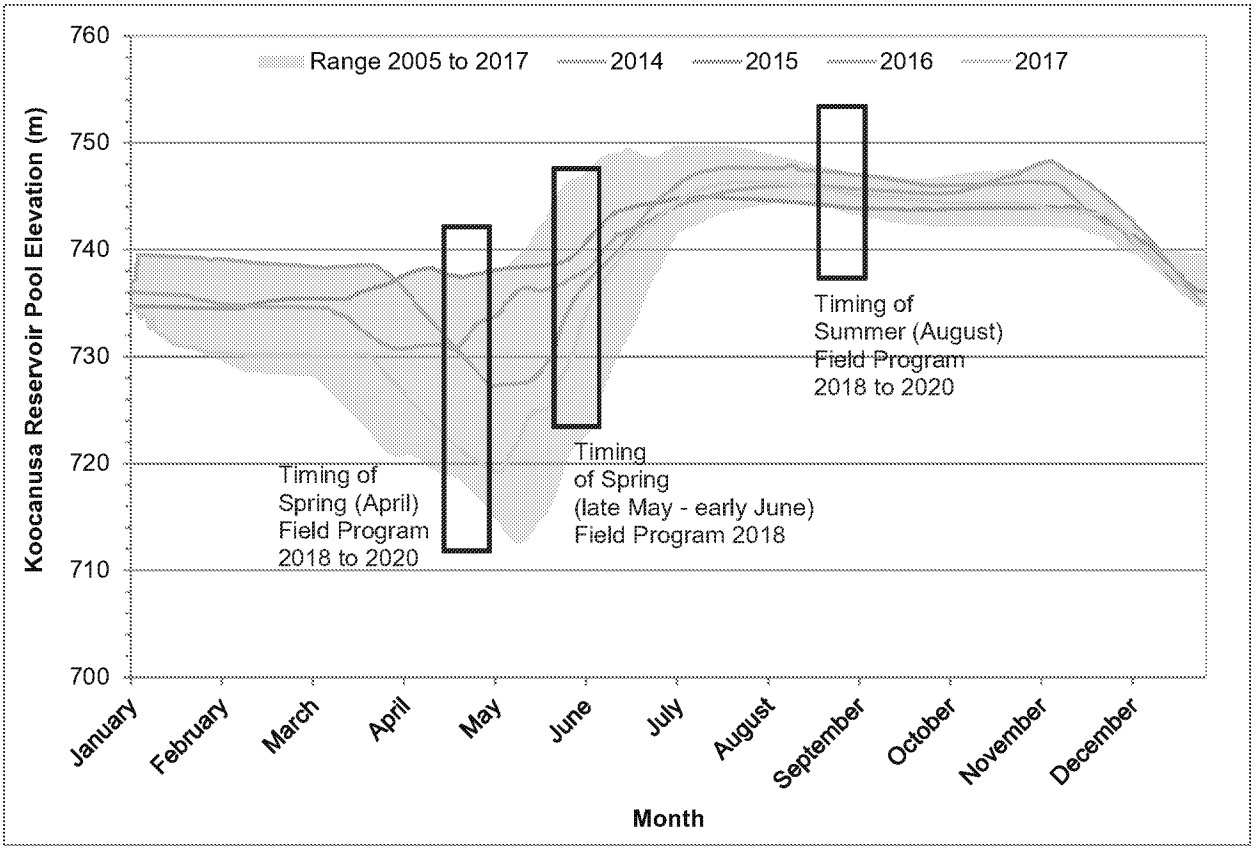


Figure 1.2: Koocanusa Reservoir Water Surface (Pool) Elevation, 2014 to 2017

Notes: Shaded area is the historical daily range of water levels from 2005 to 2017. Data from United States Army Corps of Engineers (USACE 2017).

Ktunaxa Territory is divided into traditional land districts historically associated with key actors in the Ktunaxa creation story, but also with specific key resources and with specific Ktunaxa individuals or lineages that held particular authority and responsibility for stewardship of resources in those areas (Robertson 2010).

1.1.2 Regulatory Context

In response to concerns of increasing aqueous concentrations of selenium, cadmium, nitrate and sulphate[1], as well as calcite formation within watercourses in the Elk Valley, the BC Minister of Environment and Climate Change Strategy (ENV) issued a Ministerial Order in April 2013 (Number [No.] M113). The Order outlined a framework to develop the Elk Valley Water Quality

[1] Collectively referred to as "Order constituents" because they, and calcite, are specifically named in Provincial Order M113.

Plan (EVWQP) to allow for continued mining development in the Elk Valley while achieving the following outcomes:

- protection of aquatic ecosystem health;
- management of bioaccumulation of contaminants in the receiving environment (including fish tissue);
- protection of human health; and
- protection of groundwater.

In 2013 and 2014, Teck worked with Ktunaxa Nation Council (KNC), governments, other stakeholders and scientists to develop the EVWQP (Teck 2014). The EVWQP was designed for the Elk River watershed and the Canadian portion of Koocanusa Reservoir[2], which represents the Designated Area[3] referred to in Order M113. The EVWQP divided the Designated Area into six management units (MUs) based on geographic features, major tributaries and hydrodynamic characteristics, five of which are in the Elk River watershed, while the Canadian portion of Koocanusa Reservoir represents the sixth MU[4] (Figure 1.1).

The process of developing the EVWQP incorporated water, sediment, and biological monitoring data to characterize baseline conditions, assess current conditions with respect to aquatic ecosystem and human health, and project future water quality. The water quality assessment identified that selenium and nitrate concentrations in the Elk River were routinely above water quality guidelines, and were increasing in many areas (Windward et al. 2014; Teck 2014). There was evidence of selenium bioaccumulation in fish and other biota, and localized effects were observed near some mine sources. Results from Teck's research and technology development program revealed that active water treatment was the most effective option for stabilizing selenium and nitrate concentrations in the near-term (Teck 2014).

Short-, medium-, and long-term targets were derived for specific ("Order") stations in the EVWQP to protect aquatic ecosystem health at a MU scale (Teck 2014). The EVWQP also

[2] For the purposes of this study, Koocanusa Reservoir refers to lands and waters wholly contained within Canada.

[3] The Designated Area as defined by Ministerial Order M113 and Permit 107517 is: "a portion of southeastern British Columbia that contains the Elk Valley Watershed and the portion of Lake Koocanusa within Canada. References to the Elk Valley are references to the Designated Area."

[4] Koocanusa Reservoir has very different habitat characteristics (e.g., it is a managed reservoir with large annual fluctuations in water depths and surface area) from the Elk River watershed (flowing streams with some connected, typically small, lentic habitats). Biological assemblages also differ between the reservoir and Elk River watershed. Therefore, the study design for monitoring in Koocanusa Reservoir has been developed separately, but monitoring results will be included in the RAEMP report.

outlined the initial implementation plan for achieving targets including phased commissioning of active water treatment facilities (AWTF) in relevant areas of the watershed. Teck submitted the EVWQP to ENV in July of 2014. In November of 2014, ENV approved the EVWQP and issued Permit 107517[5] under the *Environmental Management Act.* Permit 107517 regulates discharges from Teck's five Elk Valley metallurgical coal mine operations in a manner consistent with the EVWQP. The Permit specifies water quality limits and site performance objectives (SPOs) for monitoring stations downstream from the mines, and outlines requirements for commissioning and operating AWTFs, tributary evaluation and management, calcite management, toxicity testing, monitoring of water quality, flow, and aquatic effects, and adaptive management and reporting.

Teck's Regional Aquatic Effects Monitoring Program (RAEMP) is also one of the requirements stipulated in Permit 107517, and the requirement for study design submission is as follows:

> *(Section 9.4) "The Permittee must implement the Regional Aquatic Effects Monitoring Program (RAEMP) as per the November 14, 2014 approval or the latest Director approved program. A final Study Design for each subsequent three-year cycle must be submitted to the Director by December 15 in the final year of each three-year cycle (i.e., next study design submitted December 15, 2017).*

Following discussion with ENV and the EMC, the RAEMP study design was submitted as a draft on December 15, 2017 to meet the Permit requirement and final on March 30, 2018. The Koocanusa Reservoir monitoring study design (this document) has been developed separately from the RAEMP study design based on differences in aquatic habitat, receptors, and stressors (e.g., management of water levels in the reservoir), but results will be incorporated in the RAEMP report as per Permit 107517 requirements. The draft Koocanusa Reservoir monitoring study design was submitted on December 15, 2017 to meet the Permit requirement. A deadline of April 30, 2018 was agreed upon for the final submission to incorporate EMC advice based on their review of the draft study design. In addition to the study design, annual reports summarizing activities and monitoring results will be provided, as stipulated in Section 10.8 of Permit 107517:

> *(Section 10.8) "The Permittee must prepare on an annual basis a report summarizing activities and monitoring results. The report must be submitted to the Lake Koocanusa Monitoring and Research Working Group (Lake Koocanusa Working Group) and the EMC by June 30 of each year."*

[5] Permit 107517 was most recently amended in November 16, 2017.

Although implementation of the Koocanusa Reservoir monitoring program is the responsibility of Teck, the program was designed with input and advice from the EMC. The EMC consists of representatives from Teck, ENV, the Ministry of Energy and Mines, the KNC, Interior Health Authority, and an Independent Scientist (IS)[6]. The EMC reviews submissions and provides technical advice and input to Teck and the ENV Director, as stipulated in Permit 107517. A summary of EMC meetings and feedback related to this study design are provided in Table 1.1.

Table 1.1: EMC Meeting and Input Feedback Dates

EMC Meeting Date	Feedback Date
24-Apr-17	10-May-17
16-Jun-17	29-Jun-17
23-Oct-17	09-Nov-17
17-Nov-17	28-Nov-17
22-Jan-18	07-Feb-18
21-Feb-18	16-Mar-18

1.1.3 Linkages to Teck's Adaptive Management Plan

Consistent with Section 11 of Permit 107517, Teck also developed an Adaptive Management Plan (AMP) to support implementation of the EVWQP, achieve water quality and calcite targets, ensure human health and the environment are protected (and where necessary, restored), and facilitate continuous improvement of water quality in the Elk Valley (Teck 2016a). The AMP is structured around a set of six overarching environmental Management Questions that collectively address the environmental management objectives of the AMP and the EVWQP. In addition, the AMP identifies Key Uncertainties under each Management Question, which if reduced, either help confirm that Teck's current management actions are appropriate or lead to adjustments that would better satisfy EVWQP objectives. Monitoring data and evaluations conducted within the monitoring program are designed primarily to provide supportive information to help answer AMP Management Question #5 (currently worded as "Does monitoring for mine-related effects indicate that the aquatic ecosystem is healthy?"), and Key Uncertainty 5.1 (currently worded as "How will monitoring data be used to identify potentially important mine-related effects on aquatic ecosystem health at a management unit scale?"). The RAEMP, including results from the Koocanusa Reservoir monitoring program, will evaluate data to address these AMP questions. Should management responses be required associated with findings from this analysis, additional investigations or adjustments may be required.

[6] Environment Canada has also agreed to provide its perspectives on matters related to Permit 107517 and the Committee's activities, on a case-by-case basis when requested by the Committee. To date, the Committee has not called on Environment Canada to participate.

Data and analysis conducted under the RAEMP, will also contribute to answering AMP Management Question #2, (currently worded as "Will aquatic ecosystem health be protected by meeting the long-term site performance objectives?) by assessing the aquatic ecosystem under a range of current conditions and identifying areas where biological effects may be occurring due to one or more mine-related constituents. The RAEMP will also contribute information to help reduce Key Uncertainty 2.1 (currently worded as "How will the science-based benchmarks be validated and updated?") and Key Uncertainty 2.2 (currently worded as "How will the integrated assessment methodology used to derive area-based SPOs be validated and updated?"). Assessments associated with these AMP components will primarily be conducted separately from the RAEMP.

Specific information collected under the RAEMP will also be used to support evaluation required for Management Question 6 (currently worded as "Is water quality being managed to be protective of human health?"). Assessments associated with these AMP components will be conducted outside the RAEMP.

Finally, the AMP is required by Permit 107517 to contain "Triggers" for management actions. Teck continues to work with the EMC to develop triggers for management actions that are based on biological monitoring results. The Koocanusa Reservoir monitoring study design presented herein was updated to reflect discussions on this topic with the EMC at meetings in January and February, 2018. Once triggers are finalized, additional modifications to the design may be required so that monitoring data can be appropriately evaluated relative to the biological triggers.

1.2 Koocanusa Reservoir Monitoring Program (MU 6)

1.2.1 Overview

Teck initiated monitoring in 2013 with a study on sediment characteristics in the Canadian portion of Koocanusa Reservoir (Minnow 2014). Following this, a three-year comprehensive monitoring program was initiated in 2014 to characterize and compare chemical and biological conditions upstream and downstream of the Elk River inflow to the reservoir. Results of monitoring completed in 2014 and 2015 were reported (Minnow 2015b, 2016) in accordance with reporting requirements (i.e., Section 10.8 of Permit 107517). Results of all three years of monitoring (2014 to 2016) were combined into a final interpretive report (Minnow 2018b), which included a summary of Teck's water monitoring results (Teck 2016b, 2017) and results from the burbot study (Minnow 2015a). This document, informed by the results from the aforementioned program, outlines the study design for the next three years of monitoring in Koocanusa Reservoir (2018 to 2020).

1.2.2 Objectives and Questions

The general objective of the RAEMP (which is the overarching monitoring program including work being completed in Koocanusa Reservoir) is to monitor, assess, and interpret indicators of aquatic ecosystem condition related to mine operations, and to inform adaptive management relative to expectations established in approved plans for mine development and in Permit 107517

These general objectives will be met through repeated cycles of monitoring by evaluating the data to answer the RAEMP questions. Through several discussions with the EMC and Teck, the questions from the last RAEMP design (Minnow 2015a) were updated to consider linkage with the AMP, as follows:

1. Has there been a change in condition since previous monitoring cycles with respect to fish and benthic invertebrate population/community indicators, water quality, sediment quality, calcite, and/or tissue selenium concentrations?
2. Were any identified changes unexpected (i.e., inconsistent with model predictions or general expectations[7])?
3. Does the weight of evidence indicate the unexpected changes are mine-related?
4. What does the weight of evidence indicate about current or future[8] ecosystem conditions in each management unit and regionally, considering the observed type, magnitude, spatial extent, and/or rate of change?

Recognizing that conditions in Koocanusa Reservoir are different than the other five MUs, questions specific to the Canadian portion of the reservoir have been developed to focus the monitoring program for 2018 to 2020. These are as follows:

- Are concentrations of mine-related water quality constituents different downstream of the Elk River compared to upstream?
- Are concentrations of key mine-related water (i.e., nitrate, selenium, sulphate, and cadmium) quality constituents changing over time, are the changes consistent with projections, and are concentrations below respective guidelines and SPOs?

[7] "General expectations" may include predictions that were presented in approved plans in a narrative or semi-quantitative form. General expectations also include biological characteristics that are considered to be consistent with expectations based on observed chemical concentrations and calcite conditions relative to site-specific effect benchmarks.

[8] Although the monitoring data reflect existing conditions, evaluation of trends may indicate a pattern of unexpected degradation indicative of potential future concern.

- Is productivity (based on nutrient concentrations in water) different downstream of the Elk River compared to upstream and is productivity changing over time?
- Are concentrations of mine-related constituents in sediment that benthic invertebrates are exposed to different downstream of the Elk River compared to upstream and are concentrations changing over time?
- Do phytoplankton, zooplankton, and/or benthic invertebrate community structure differ downstream of the Elk River compared to upstream, and are the differences changing over time?
- Are selenium concentrations in zooplankton different downstream of the Elk River compared to upstream, and are the differences changing over time?
- Are selenium concentrations in benthic invertebrates greater than guidelines or effect thresholds, do they differ downstream of the Elk River compared to upstream, and are the differences changing over time?
- Is fish health different downstream of the Elk River compared to upstream, and are differences in fish health endpoints changing over time?
- Are there differences in fish recruitment downstream of the Elk River compared to upstream?
- Are selenium concentrations in fish tissue greater than guidelines or effect thresholds, do they differ downstream of the Elk River compared to upstream, and are the differences changing over time?

2 SUMMARY OF 2014 TO 2016 MONITORING CYCLE RESULTS

2.1 General Overview

The 2014 to 2016 studies in Koocanusa Reservoir assessed water quality, sediment quality, primary productivity (i.e., seston biomass and chlorophyll-a in water), phytoplankton and zooplankton community structure, benthic invertebrate community structure, fish health, and zooplankton, benthic invertebrate, and fish tissue metal concentrations (Minnow 2018b). The interpretive report was submitted to ENV on June 30, 2017, as required by Permit 107517. Following this, the EMC reviewed the report and provided technical advice and input. The final report was revised based on EMC input, and submitted to the ENV on January 31, 2018. Key results from the 2014 to 2016 monitoring are summarized below and were used to inform the study design described herein.

2.2 Water Quality

Water quality profiles indicated that the water column was oxygenated with slightly alkaline pH. Concentrations of nitrate, selenium, and sulphate were similar in water samples collected at middle and bottom depths at downstream sample locations, but were typically lower in samples collected at the surface. Concentrations of dissolved cadmium were mainly non-detectable both upstream and downstream of the Elk River. Differences between upstream and downstream concentrations were greater in 2016 than 2015 for both nitrate and selenium, but mean concentrations at the downstream areas in 2016 were similar to or less than those observed in 2015. Results were less consistent in 2014 when the upstream station was situated closer to the Elk River. In 2015, the upstream station was moved approximately 3.5 km further upstream (based on recommendations provided by the EMC). Sulphate concentrations did not differ significantly downstream versus upstream of the Elk River. SPOs[9] for nitrate, selenium, sulphate, and dissolved cadmium were consistently met at the Order station downstream from the Elk River (RG_DSELK).

2.3 Sediment Quality

Sediment samples collected in the reservoir both downstream and upstream from the Elk River were mostly silt (≥60%), with sand and clay comprising smaller fractions, and total organic carbon (TOC) concentrations ranging from 0.9 to 1.7%. Concentrations of most metals and polycyclic aromatic hydrocarbons (PAHs) in sediment were higher downstream from the Elk

[9] The SPOs are consistent with the BC water quality guidelines.

River compared to upstream, but did not increase over the three year study. Concentrations of some metals (upstream and downstream) and PAHs (downstream only) in sediments were above the lower provincial sediment quality guidelines, but none exceeded the upper guidelines (BCMOE 2017b).

2.4 Plankton and Productivity

Low concentrations of phosphorus and chlorophyll-a, along with low seston and zooplankton biomass, indicated that the reservoir is oligotrophic. Phytoplankton communities in the reservoir were numerically dominated by diatoms, and to a lesser extent, Chrysophytes. There were no significant differences in overall phytoplankton density, biomass, or richness between downstream and upstream areas over the three years. Community structure was similar between upstream and downstream areas, except for greater Cyanophyte biomass at the downstream area, which was considered to have low ecological significance because this group represented <1% of the community.

The zooplankton community was numerically dominated by rotifers and copepods, with relatively low numbers of cladocerans. No consistent differences were observed between downstream and upstream areas in overall zooplankton density, biomass, richness, or in absolute or relative density or biomass of copepods or rotifers, over the three year study. Abundance and biomass of cladocerans tended to be lower downstream from the Elk River compared to upstream. Selenium concentrations in zooplankton were similar between downstream and upstream areas in each of the three years, and were greater than the BC interim chronic dietary guideline of 4 µg/g dry weight (dw) in 2015 only, but were consistently less than the Level 1 benchmarks developed in the EVWQP for effects to benthic invertebrates (13 mg/kg dw) and dietary effects to fish (11 mg/kg dw).

2.5 Benthic Invertebrates

Benthic invertebrate communities were primarily composed of oligochaetes (mostly immature Tubificinae), insects (various species of chironomids), and ostracods in each of the three sample years. Overall community density and richness did not differ significantly between upstream and downstream areas in the three study years. Community structure differed between areas, particularly with respect to ostracods, which had higher average density at the downstream area compared to the upstream area over the three years of study. Densities of oligochaetes were also higher at the downstream area compared to the upstream area.

Mean benthic invertebrate tissue selenium concentrations were higher at the downstream area than the upstream area, and were greater than the BC interim chronic dietary guideline of

4 µg/g dw, but were consistently less than the Level 1 benchmarks developed in the EVWQP for effects to benthic invertebrates (13 mg/kg dw) and dietary effects to fish (11 mg/kg dw).

2.6 Fish

Largescale sucker (*Catostomus macrocheilus*), northern pikeminnow (*Ptychocheilus oregonensis*), peamouth chub (*Mylcheilus caurinus*), redside shiner (*Richardsonius balteatus*), and yellow perch (*Perca flavescens*) were the most commonly captured species at each of the three study areas (i.e., Sand Creek, Elk River, and Gold Creek areas) based on the fishing techniques used, locations sampled, and time of year. Less-commonly captured species include bull trout (*Salvelinus confluentus*), burbot (*Lota lota*), kokanee (*Oncorhynchus nerka*), longnose sucker (*Catostomus catostomus*), mountain whitefish (*Prosopium williamsoni*), pumpkinseed (*Lepomis gibbosus*), rainbow trout (*Oncorhynchus mykiss*), slimy sculpin (*Cottus cognatus*), and westslope cutthroat trout (*Oncorhynchus clarkii lewisi*).

Fish health surveys, which focused on endpoints indicative of fish survival (mean age), growth (body size-at-age), reproduction (relative gonad weight) and energy storage (relative liver weight and overall condition), showed no consistent patterns among fish species, sexes, or sampling years. Peamouth chub and redside shiner showed a relatively high incidence of tapeworms; gonadal development appeared to be inhibited by the presence of tapeworms, which is consistent with typical responses of cyprinids (Carter et al. 2005).

Muscle, whole body, and/or ovary selenium concentrations were determined for bull trout, burbot, kokanee, largescale sucker, mountain whitefish, northern pikeminnow, peamouth chub, rainbow trout, redside shiner, westslope cutthroat trout, and yellow perch. In muscle or whole body, the mean selenium concentration of some species were greater than the BC guideline of 4 µg/g dw, but mean concentrations were less than the United States Environmental Protection Agency (USEPA)[10] criteria of 11.3 µg/g dw in muscle and 8.5 µg/g dw in whole bodies. Mean ovary selenium concentrations were greater than the BC chronic guideline of 11 µg/g dw for peamouth chub. All species except redside shiner and northern pikeminnow had mean ovary selenium concentrations less than the Level 1 benchmark for reproductive effects to fish (18 mg/kg dw), and the 2016 USEPA criterion of 15.1 µg/g dw, although not all species had enough individuals to meet the recommendation that at least eight fish should be used to compare the mean values to the BC guideline. Northern pikeminnow had mean ovary selenium concentrations above the Level 1 benchmark at the Elk River area in one of the three years they were sampled (2014), when ovaries were relatively undeveloped. Mean redside shiner ovary

[10] The USEPA (2016) criteria were published after the BC selenium water quality guideline (2012), reflecting more recent research.

selenium concentrations were above the Level 1 benchmark at both the Elk River and the Sand Creek areas in both 2015 and 2016.

3 2018 TO 2020 MONITORING CYCLE STUDY DESIGN

3.1 General Overview

The monitoring program will occur over three years (2018 to 2020) to determine if water, sediment, and/or biota in the reservoir are changing, and if those changes are attributable to influences from the Elk River and associated upstream mining activities. Questions that frame the monitoring program are outlined in Section 1.2.2. In order to answer these questions, the data collected will focus on:

- Water (physical and chemical), sediment (physical and chemical), and tissues of zooplankton, benthic invertebrates, and fish (for chemical analysis);
- Phytoplankton, zooplankton, and benthic invertebrates for analysis of community structure; and
- Fish measurements for assessment of fish health and recruitment.

Based on the Conceptual Site Model provided in the RAEMP for the six MUs, Table 3.1 shows assessment and measurement endpoints for each of the receptors in the monitoring program for Koocanusa Reservoir (MU6). The schedule of sampling over the 2018 to 2020 cycle is shown in Table 3.2. Measurement endpoints specific to each sample type (Table 3.1) will be statistically evaluated to identify potential differences downstream compared to upstream from the Elk River, and for endpoints that differ among areas, to determine if they are consistent among years (2018 to 2020) or suggest an increasing or decreasing pattern. Data will also be compared to the 2014 to 2016 monitoring data where data are available and appropriate for comparison.

Proposed sampling locations are very similar to the first monitoring cycle (2014 to 2016; Minnow 2018b). As shown on Figure 3.1, the Elk River area represents the confluence of the Elk River with Koocanusa Reservoir (RG_ER). The Sand Creek area (RG_SC) and upstream stations (RG_TN) are located upstream of the Elk River confluence. The Gold Creek area (RG_GC) and downstream (RG_T4) stations are located downstream of the Elk River confluence. These sampling locations are the focus for water, sediment, plankton, benthic invertebrate, and/or fish data collection.

Fluctuations of water levels within the reservoir (Figure 1.2) result in seasonal and annual variation in water volume and flow characteristics, as well as annual dewatering of large littoral (shallow shoreline) areas. These hydraulic factors are anticipated to influence chemical and biological characteristics within the reservoir and will be considered in the final selection of sampling locations within the identified areas of focus.

Table 3.1: **Summary of Receptors, Assessment Endpoints, Measurement Endpoints, and Evaluation Criteria for Koocanusa Reservoir, 2018 to 2020**

Receptor Group	Focal Species (if Relevant)	Assessment Endpoint	Measurement Endpoint	Evaluation Criteria	Indicator Type
Fish	Peamouth chub and redside shiner	Population health assessment	Survival (age)	Comparison of results between upstream and downstream of the Elk River and to past observations	Direct
			Growth (body weight against age)		
			Reproduction (gonad weight against body weight)		
			Energy storage (condition - body weight against length and liver weight against body weight)		
			Tissue selenium concentrations	Comparison of results relative to guidelines and effect benchmarks, between upstream and downstream of the Elk River, and to past observations	Indirect
	Redside shiner	Recruitment (non-lethal assessment)	Survival (length frequency distribution)	Comparison of results between upstream and downstream of the Elk River and to past observations	Direct
			Growth (whole body weight and length)		
			Reproduction (relative abundance / % composition of young-of-the-year)		
			Energy storage (condition - body weight against length)		
	Northern pikeminnow, yellow perch, bull trout, etc.	Fish health, and human health risk from fish consumption	Tissue chemistry	Comparison of results relative to guidelines and effect benchmarks, between upstream and downstream of the Elk River, to past observations, and to human health effect benchmarks (evaluated outside of the monitoring program)	Indirect
Phytoplankton and zooplankton	Not applicable	Abundance and assemblage	Density	Comparison of results between upstream and downstream of the Elk River and to past observations	Direct
			Richness		
			Biomass		
			Major community group		
			Tissue selenium concentrations	Comparison of results relative to guidelines and effect benchmarks, between upstream and downstream of the Elk River, and to past observations	Indirect
Benthic invertebrates	Not applicable	Abundance and assemblage	Density	Comparison of results between upstream and downstream of the Elk River and to past observations	Direct
			Richness		
			Major community group		
			Tissue selenium concentrations	Comparison of results relative to guidelines and effect benchmarks, between upstream and downstream of the Elk River, and to past observations	Indirect
All	Not specific	Not specific	Sediment chemistry	Comparison of results relative to guidelines, between upstream and downstream of the Elk River, and to past observations	Indirect
			Water chemistry	Comparison of concentrations of mine-related constituents relative to SPOs and guidelines, nutrients relative to trophic classifications, between upstream and downstream of the Elk River, and to past observations	Indirect

Table 3.2: **Overview of the 2018 to 2020 Koocanusa Reservoir Monitoring Study Design ***

Management Unit	Exposure Type	Biological Area Code	Biological Area Description	Spring 2018												Summer 2018												Spring 2019 and 2020						Summer 2019 and 2020					
				Water [b]			Sediment	Benthic Invertebrates	Fish							Water [b]			Sediment	Plankton			Benthic Invertebrates	Fish				Water [b]		Benthic Invertebrates	Fish			Water [b]		Sediment	Plankton	Benthic Invertebrates	Fish
				Elk River Mixing Study [a]	Chemistry	*In Situ* Water Quality [c]	Quality	Tissue Chemistry	Fish Health [d]		Tissue Chemistry					Elk River Mixing Study [a]	Chemistry	*In Situ* Water Quality [c]	Quality	Phytoplankton Community	Zooplankton Tissue Chemistry	Zooplankton Community	Community	Tissue Chemistry	Sport Fish Tissue Chemistry [h]	Redside Shiner Recruitment [e]		Chemistry	*In Situ* Water Quality [c]	Tissue Chemistry	Tissue Chemistry			Chemistry	*In Situ* Water Quality [c]	Quality	Zooplankton Tissue Chemistry	Tissue Chemistry	Redside Shiner Recruitment [e]
									Peamouth Chub	Redside Shiner	Northern Pikeminnow [g]	Peamouth Chub [f]	Redside Shiner [f]	Sport Fish [h]																		Peamouth Chub [f]	Redside Shiner [f]								
6	Upstream of the Elk River	RG_SC	near the mouth of Sand Creek	1	1	1	5	5	55	80	10	10	10	8	1	1	1	-	-	-	-	-	-	8	100	1	1	-	10	10	1	1	-	-	-	100
		RG_TN	near the RG_KERRRD permitted water quality station		1	1	-	1	-	-	-	-	-	-		1	5	5	5	10	5	5	1	-	-	1	1	1	-	-	1	5	5	5	1	-
	Elk River	RG_ER	near the mouth of Elk River		1	1	5	5	55	80	10	10	10	8		1	1	-	-	-	-	-	-	8	100	1	1	-	10	10	1	1	-	-	-	100
	Downstream of the Elk River	RG_T4	near the RG_GRASMERE permitted water quality station		1	1	-	1	-	-	-	-	-	-		1	5	5	5	10	5	5	1	-	-	1	1	1	-	-	1	5	5	5	1	-
		RG_GC	near the mouth of Gold Creek		1	1	5	5	55	80	10	10	10	8		1	1	-	-	-	-	-	-	8	100	1	1	-	10	10	1	1	-	-	-	100

[a] the Elk River mixing study will occur in April and June (Spring), and in August 2018.

[b] depth-integrated water samples will be collected in accordance to Teck's Koocanusa Reservoir Water Quality Monitoring Plan, including the frequency and analyzed parameters for the permitted water quality program have been provided in Table 3.3.

[c] *in situ* water quality parameter suite includes water temperature, dissolved oxygen, pH, and specific conductance collected as a profile in 1-m intervals.

[d] lethal collection of 20 female and 35 male peamouth chub (n=55), and 35 female and 45 male redside shiner (n=80) for assessment of lethal EEM endpoints.

[e] collection of young-of-the-year (YOY) redside shiner for non-lethal EEM endpoints.

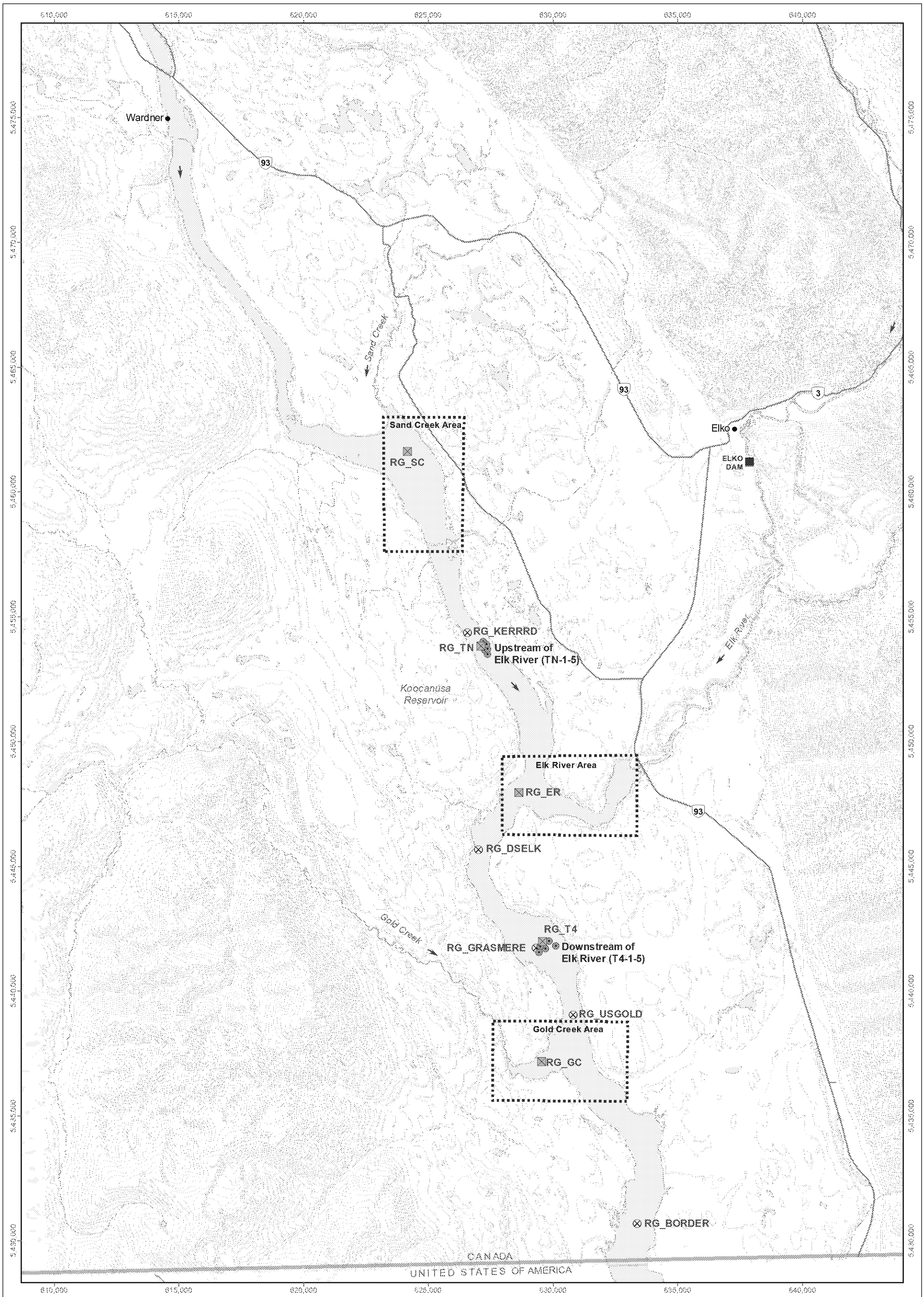
[f] lethal collection of ovaries and muscle from 10 female peamouth chub and redside shiner.

[g] lethal collection of ovaries and muscle from 10 female northern pikeminnow (sampled later in Spring [early June] to attempt to collect pikeminnow with more developed ovaries).

[h] non-lethal collection (with the exception of yellow perch) of up to a total of 8 sport fish per species (e.g., bull trout and mountain whitefish) in the spring and summer sampling events.

"-" indicates that no sampling is occurring for a specific monitoring component during that time period.

* numerical values indicate the number of samples required for the monitoring component.



LEGEND

- Sediment, Plankton (Community and Tissue), and Benthic Invertebrate (Community and Tissue) Sampling Location
- Water Quality and *In Situ* Station
- Permitted Water Quality Station
- Approximate Fish (fish health, recruitment, and fish tissue), Littoral Sediment, and Benthic Invertebrate Tissue Sampling Area

Sampling Locations for Water Quality, Sediment, Benthic Invertebrates, Plankton, and Fish in Koocanusa Reservoir, 2018 to 2020

0 2.5 5 10
km

N W E S

Projection: North American Datum 1983 UTM Zone 11

Date: April 2018
Project 177202.0048

minnow environmental inc.

Figure 3.1

Document Path: S:\Projects\177202\177202 0048 - Teck Koocanusa 2017\Mapping\Study Design\17-48 Fig 3.1 Sampling Locations.mxd

3.2 Water Quality

3.2.1 Overview

Consistent with monitoring completed over the 2014 to 2016 period, *in situ* water quality (field parameters) will be measured at each fish sampling area and at the upstream and downstream stations in April and August in each of 2018, 2019, and 2020 (Figure 3.1). Water chemistry data from Teck's permitted water quality monitoring in the reservoir will also be included (see Figure 3.1 for sample locations). Additional water quality samples will be collected concurrently with biological samples. An assessment of mixing of the Elk River within Koocanusa Reservoir (based on conductivity and temperature measurements) will be completed in 2018 (i.e., April, June, and August sampling).

3.2.2 Field Parameters

In association with biological sampling, *in situ* measurements of water quality will be completed in April and August from 2018 to 2020 (Table 3.2). Water temperature, dissolved oxygen (DO), pH, and specific conductance (i.e., temperature-standardized measurement of conductivity) will be measured as vertical profiles at one meter intervals starting just below the water surface. The *in situ* water quality measurements will be taken with a calibrated YSI 556 MDS (Multiparameter Display System) meter equipped with a YSI 6820 Sonde, or similar portable multi-parameter unit. *In situ* water quality will be taken from a central location within each fishing area (Sand Creek, Elk River, and Gold Creek), and at each of the five biological sampling stations located upstream (RG_TN-1 through RG_TN-5) and downstream of the Elk River (RG_T4-1 through RG_T4-5). Additional water quality information collected to support the interpretation of biological data will include Secchi depth, and observations of water colour and clarity.

3.2.3 Chemistry

At a minimum, routine water quality monitoring will be conducted by Teck to meet the requirements of Permit 107157 (see Tables 10 and 11 within the permit). Additional routine water quality monitoring is undertaken by Teck in accordance with Teck's Koocanusa Reservoir Water Quality Monitoring Plan (Table 3.3; Appendix A). As per the West Line Creek Active Water Treatment Facility (WLC AWTF) - Bypass Approval (February 26, 2018), quarterly selenium speciation sampling will also be completed by Teck at the Order station (RG_DSELK, EMS E300230, Table 3.3) until the earlier of August 30, 2018 or receipt of notice of commencement of commissioning of the WLC AWTF and Advanced Oxidation Process (AOP).

Initially, an *in situ* water quality profile will be conducted, and if there is a thermocline (sustained change of 1°C over 1 m change in depth), a composite sample formed from three

Table 3.3: Summary of Routine Water Monitoring Program

Permitted Station		ENV EMS Number	Sampling Parameter and Associated Monitoring Frequency						
			Field Parameters[a]	Conventional Parameters[b]	Major Ions[c]	Nutrients[d]	Total and Dissolved Metals Scan[e]	Secchi Depth and Chlorophyll-a	Selenium Speciation Sampling[f]
Order	RG_DSELK	E300230	M	M/EH	M/EH	M/EH	M/EH	M	Q
Receiving	RG_KERRRD	E300095	M	M/EH	M/EH	M/EH	M/EH	M	-
	RG_GRASMERE	E300092	M	M/EH	M/EH	M/EH	M/EH	M	-
	RG_USGOLD	E300093	M	M/EH	M/EH	M/EH	M/EH	M	-
	RG_BORDER	E300094	M	M	M	M	M	M	-

Notes:

M = Monthly frequency.

M/EH = Monthly frequency of one epilimnetic composite of water sampled from three depths (e.g., 1 m, 5 m, 10 m) and another hypolimnetic composite of water sampled from three depths (e.g., 20 m, 32 m, 45 m).

Q = Quarterly frequency.

[a] Field parameters include specific conductance, dissolved oxygen, temperature, pH, and vertical profiles of dissolved oxygen and temperature.

[b] Conventional Parameters include specific conductance, total dissolved solids, total suspended solids, hardness, alkalinity, dissolved organic carbon, total organic carbon, turbidity.

[c] Major Ions include bromide, fluoride, calcium, chloride, magnesium, potassium, sodium, sulphate.

[d] Nutrients include ammonia, nitrate, nitrite, TKN, orthophosphate, total phosphorous.

[e] Metals (dissolved and total fractions) include aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, tin, titanium, uranium, vanadium, and zinc.

[f] Additional selenium speciation sampling in support of EVWQP baseline information and to fulfill the requirements of the West Line Creek Active Water Treatment Facility Bypass Approval (February 26, 2018).

evenly-spaced grab samples will be collected throughout the epilimnion, and another composite of three evenly-spaced grab samples from the hypolimnion.

If a thermocline is not evident, a sample will be collected at 3 m from the surface, 3 m from the substrate, and at the mid-point of the water column.

Water chemistry will be analyzed from ten sample locations (Figure 3.1). Permit 107517 requires the collection of water samples at five permitted stations located within the Canadian portion of the reservoir (Figure 3.1: 'Permitted Water Quality Station'). Four of the stations are referred to as receiving water sampling sites (RG_KERRRD, RG_GRASMERE, RG_USGOLD, RG_BORDER), while the fifth station (RG_DSELK) is an Order station, for which SPOs have been established. Water samples are collected at these permitted stations on a monthly basis per Permit 107517 requirements, and are sampled weekly from April 1st to July 15th as part of Teck's Koocanusa Reservoir Water Quality Monitoring Plan (Appendix A). An additional five water quality samples (RG_SC, RG_TN, RG_ER, RG_T4, and RG_GC; Figure 3.1: 'Water Quality Station') will also be collected concurrent with other program components (Table 3.2 and Figure 3.1) Water sampling methods for the additional sites will be collected following Teck's Koocanusa Reservoir Water Quality Monitoring Plan (Appendix A).

3.2.4 Laboratory Analysis

Water samples will be analyzed according to details provided in Appendix A for the parameters listed in Table 3.3. Analyses will be completed in accordance with procedures described in the most recent edition of the "British Columbia Laboratory Methods Manual for the Analysis of Water, Wastewater, Sediment, Biological Materials, and Discrete Ambient Air," as per Permit 107517 conditions (Province of BC 2015).

The accuracy and precision of laboratory data will be judged based on the ability to achieve minimum laboratory reporting limits (LRLs; Table 3.4), blank samples, and analysis of matrix spikes, laboratory duplicates, and certified reference materials (CRMs).

3.2.5 Data Analysis

Results from the data analysis will be used to address the following questions:

- Are concentrations of mine-related water quality constituents different downstream of the Elk River compared to upstream?
- Are concentrations of key mine-related water quality constituents changing over time, are the changes consistent with projections, and are concentrations below respective guidelines and SPOs?

Table 3.4: **Laboratory Reporting Limits (LRLs) for Water and Sediment Samples**

Analyte	Water [a]		Sediment	
	Units	LRL	Units	LRL
Moisture	-	-	%	0.25
pH	-	-	pH	0.1
% Gravel	-	-	%	1.0
% Sand	-	-	%	1.0
% Silt	-	-	%	1.0
% Clay	-	-	%	1.0
Total Organic Carbon (TOC)	mg/L	0.5	%	0.05
Dissolved Organic Carbon (DOC)	mg/L	0.5	-	-
Hardness (as CaCO3)	mg/L	0.50	-	-
Turbidity	NTU	0.10		
Alkalinity	mg/L	1	-	-
Total Dissolved Solids (TDS)	mg/L	10	-	-
Total Suspended Solids (TSS)	mg/L	1.0	-	-
Ammonia, Total (as N)	mg/L	0.0050	-	-
Bromide (Br)	mg/L	0.050	-	-
Chloride (Cl)	mg/L	0.500	-	-
Fluoride (F)	mg/L	0.020	-	-
Nitrate (as N)	mg/L	0.0050	-	-
Nitrite (as N)	mg/L	0.001	-	-
Total Kjeldahl Nitrogen	mg/L	0.050	-	-
Phosphorus (P)-Total	mg/L	0.0020	-	-
Orthophosphate	mg/L	0.0010	-	-
Sulphate (SO4)	mg/L	0.30	-	-
Acenaphthylene	-	-	mg/kg dw	0.005
Anthracene	-	-	mg/kg dw	0.004
Benz(a)anthracene	-	-	mg/kg dw	0.01
Benzo(a)pyrene	-	-	mg/kg dw	0.01
Benzo(b)fluoranthene	-	-	mg/kg dw	0.01
Benzo(b+j+k)fluoranthene	-	-	mg/kg dw	0.01
Benzo(g,h,i)perylene	-	-	mg/kg dw	0.01
Benzo(k)fluoranthene	-	-	mg/kg dw	0.01
Chrysene	-	-	mg/kg dw	0.01
Dibenz(a,h)anthracene	-	-	mg/kg dw	0.005
Fluoranthene	-	-	mg/kg dw	0.01
Fluorene	-	-	mg/kg dw	0.01
Indeno(1,2,3-c,d)pyrene	-	-	mg/kg dw	0.01
2-Methylnaphthalene	-	-	mg/kg dw	0.01
Naphthalene	-	-	mg/kg dw	0.01
Phenanthrene	-	-	mg/kg dw	0.01
Pyrene	-	-	mg/kg dw	0.01
Aluminum (Al)	mg/L	0.003	mg/kg dw	50
Antimony (Sb)	mg/L	0.0001	mg/kg dw	0.1
Arsenic (As)	mg/L	0.0001	mg/kg dw	0.1
Barium (Ba)	mg/L	0.00005	mg/kg dw	0.5
Beryllium (Be)	mg/L	0.00002	mg/kg dw	0.1
Bismuth (Bi)	mg/L	0.00005	mg/kg dw	0.2
Boron (B)	mg/L	0.01	mg/kg dw	5
Cadmium (Cd)	mg/L	0.000005	mg/kg dw	0.02
Calcium (Ca)	mg/L	0.05	mg/kg dw	50
Chromium (Cr)	mg/L	0.0001	mg/kg dw	0.5
Cobalt (Co)	mg/L	0.0001	mg/kg dw	0.1
Copper (Cu)	mg/L	0.0005	mg/kg dw	0.5
Iron (Fe)	mg/L	0.01	mg/kg dw	50
Lead (Pb)	mg/L	0.00005	mg/kg dw	0.5
Lithium (Li)	mg/L	0.001	mg/kg dw	2
Magnesium (Mg)	mg/L	0.005	mg/kg dw	20
Manganese (Mn)	mg/L	0.0001	mg/kg dw	1
Mercury (Hg)	mg/L	0.000005	mg/kg dw	0.005
Molybdenum (Mo)	mg/L	0.00005	mg/kg dw	0.1
Nickel (Ni)	mg/L	0.0005	mg/kg dw	0.5
Phosphorus (P)	-	-	mg/kg dw	50
Potassium (K)	mg/L	0.05	mg/kg dw	100
Selenium (Se)	mg/L	0.00005	mg/kg dw	0.2
Silver (Ag)	mg/L	0.00001	mg/kg dw	0.1
Sodium (Na)	mg/L	0.05	mg/kg dw	50
Strontium (Sr)	mg/L	0.0002	mg/kg dw	0.5
Sulphur (S)	-	-	mg/kg dw	100
Thallium (Tl)	mg/L	0.00001	mg/kg dw	0.05
Tin (Sn)	mg/L	0.0001	mg/kg dw	2
Titanium (Ti)	mg/L	0.01	mg/kg dw	1
Uranium (U)	mg/L	0.00001	mg/kg dw	0.05
Vanadium (V)	mg/L	0.0005	mg/kg dw	0.2
Zinc (Zn)	mg/L	0.003	mg/kg dw	2

[a] Total and dissolved metals will be analyzed in water. Laboratory reporting limits are the same.

- Is productivity (based on nutrient concentrations in water) different downstream of the Elk River compared to upstream and is productivity changing over time?

Vertical *in situ* water quality profiles, completed in conjunction with biological sampling, will be plotted to determine if stratification or gradients in temperature, DO, pH, and/or conductivity were observed at the sampling areas.

Monthly mean concentrations of Order constituents (i.e., nitrate, selenium, sulphate, and cadmium) at the Order station and at other stations (including samples collected during the benthic invertebrate sampling) will be compared to SPOs (for Order station) or BC water quality guidelines (other stations). The SPOs for RG_DSELK are 2 µg/L for total selenium (equivalent to the BC water quality guideline [BCMOE 2017a]), 3 mg/L for nitrate-nitrogen (equivalent to the BC water quality guideline; hereafter referred to as nitrate), 308 mg/L for sulphate (consistent with the BC water quality guideline of 309 mg/L for moderately soft/hard to hard waters [i.e., 76 – 180 mg/L hardness]), and hardness-based for dissolved cadmium[11] (consistent with the long-term BC water quality guideline). As part of Permit 107517, Teck completes an Annual Water Quality Report (e.g., Teck 2016b, 2017). A summary of the results of the annual report (e.g., summary of water quality parameters that exceeded BC guidelines, etc.) will be incorporated into the Koocanusa Reservoir report. Water chemistry for Order constituents from major inflows into MU six (i.e., Kootenay River and Elk River) will also be compared to BC guidelines.

Criteria that categorize trophic status of the reservoir will be grouped together by variable (total phosphorus and nitrogen, chlorophyll-a, Secchi depth) into six trophic classifications (Table 3.5). These classifications are Ultra-oligotrophic, Oligotrophic, Mesotrophic, Meso-Eutrophic, Eutrophic and Hyper-Eutrophic. The trophic classification used in British Columbia (Nordin 1985) will be selected for screening against monthly mean values of total phosphorus and nitrogen, chlorophyll-a, and Secchi depth from the reservoir station upstream of the Elk River and the four stations downstream of the Elk River. The comparison will be qualitative to determine if the trophic status classification is different downstream of the Elk River compared to upstream and if changes have occurred over time by comparing to results from the 2014 to 2016 study. In addition, based on input from the EMC, the ratio of nitrogen to phosphorus will be plotted at each water quality station and compared to results from 2014 to 2016.

Statistical analysis of water chemistry data will focus on monthly mean concentrations for the Order constituents (i.e., nitrate, selenium, sulphate, and cadmium) at areas upstream and

[11] Dissolved cadmium SPO is hardness dependent based on the following formula:

Dissolved cadmium (in µg/L) = $10^{0.83\log10(\text{hardness})-2.53}$ where hardness is in mg/L of $CaCO_3$

Table 3.5: Available Criteria for Trophic Status Classification

Variable	Source	Ultra-Oligotrophic	Oligotrophic	Mesotrophic	Meso-Eutrophic	Eutrophic	Hyper-Eutrophic
Total Phosphorus (µg/L)	OECD[a,h]	<4	<10	10 - 35	-	35 -1 00	>100
	Environment Canada[b]	<4	4 - 10	10 - 20	20 - 35	35 - 100	>100
	Quebec[a]	-	4 - 10	10 - 30	-	30 - 100	-
	Sweden[a]	-	<15	15 - 25	-	25 - 100	>100
	Carlson TSI[c,d]	<6	6 - 12	12 - 24	-	24 - 96	>96
	Nordin (BC Criteria)[e]	-	1 - 10	10 - 30	-	>30	-
	Nürnberg[a,f]	-	<10	10 - 30	-	31 - 100	<100
	Vollenweider and Karekes[g]	-	3 - 18	11 - 96	-	16 - 390	-
Chlorophyll-a (µg/L)	OECD	<1	<2.5	2.5 - 8	-	8 - 25	>25
	Environment Canada	<1	<2.5	2.5 - 8	-	8 - 25	>25
	Quebec	-	1 - 3	3 - 8	-	8 - 25	-
	Sweden	-	>3	3 - 7	-	7 - 40	>40
	Carlson TSI	<0.95	0.95 - 2.6	2.6 - 7.3	-	7.3 - 56	>56
	Nordin (BC Criteria)	-	0 - 2	2 - 7	-	>7	-
	Nürnberg	-	<3.5	3.5 - 9	-	9.1 - 25	>25
	Vollenweider and Karekes	-	0.3 - 4.5	3 - 11	-	2.7 - 78	-
Secchi Depth (m)	OECD	>12	>6	3 - 6	-	1.5 - 3	<1.5
	Environment Canada	>12	>6	3 - 6	-	1.5 - 3	<1.5
	Quebec	-	5 - 12	2.5 - 5	-	1 - 2.5	-
	Sweden	-	>3.96	2.43 - 3.96	-	0.91-2.43	<0.91
	Carlson TSI	>8	4 - 8	2 - 4	-	0.5 - 2	<0.25
	Nordin (BC Criteria)	-	>6	3 - 6	-	<3	-
	Nürnberg	-	-	-	-	-	-
	Vollenweider and Karekes	-	5.4 - 28	1.5 - 8.1	-	0.8 - 7	-
Total Nitrogen (µg/L)	OECD	-	-	-	-	-	-
	Environment Canada	-	-	-	-	-	-
	Quebec	-	-	-	-	-	-
	Sweden	-	<400	400 - 600	-	600 - 1,500	>1,500
	Carlson TSI	-	-	-	-	-	-
	Nordin (BC Criteria)	-	<100	100 - 500	-	500 - 1000	-
	Nürnberg	-	<350	350 - 650	-	651 - 1,200	>1,200
	Vollenweider and Karekes	-	310 - 1,600	360 - 1,400	-	390 - 6,100	-

[a] Summarized in Galvez-Cloutier and Sanchez 2007.
[b] Environment Canada 2004.
[c] Carlson 1977.
[d] Values converted from Trophic Status Index (TSI) for comparison to other classifications.
[e] Nordin 1985, Criteria used in British Columbia.
[f] Nürnberg 2001.
[g] Vollenweider and Kerekes 1980.
[h] Organisation for Economic Co-operation and Development.

downstream of the Elk River. Pairwise statistical comparisons of monthly mean concentrations between depths (surface vs. middle, surface vs. bottom, and middle vs. bottom) will be conducted by station using a paired t-test. If the assumption of normality (Shapiro-Wilks' test with significance level [α] = 0.05) is not met, the non-parametric Wilcoxon signed rank test will be used. A Bonferroni-adjusted α of 0.1/3 = 0.033 will be used for paired t-tests and Wilcoxon signed rank tests to control the Type I error rate for the n = 3 pairwise comparisons for each station. Results of these analyses will be used to determine whether depths should be analyzed separately or pooled in the analyses described below.

Statistical comparisons of Order constituents (nitrate, selenium, sulphate, and cadmium) and nutrient concentrations between permitted water quality downstream stations (i.e., RG_DSELK, RG_GRASMERE, RG_USGOLD, and RG_BORDER) and the upstream station (RG_KERRRD) will be conducted to assess potential differences. Statistical comparisons will be conducted on the mathematical differences (downstream of the Elk River – upstream of the Elk River) in monthly mean concentrations to remove the influence of season using a method analogous to a two-way ANOVA with factors *Area* and *Year*. Differences in monthly mean concentrations between areas will be tested using ANOVA (or the Kruskal-Wallis test when assumptions of normality and homogeneity of variances are not met) with factor *Year* (equivalent to testing the *Area*×*Year* interaction in a two-way ANOVA) according to the following hypothesis:

$$H_{01}: \mu_{d\_2014} = \mu_{d\_2015} = \ldots = \mu_{d\_n}$$

where μ_{d_n} represents the mean of the differences in monthly mean concentrations between upstream and downstream stations in year n (final year of data).

If a difference among years is detected (α = 0.05) then *post hoc* contrasts will be conducted to test for linear and step changes as described in Minnow (2018a). This test will assess temporal changes in the differences between upstream and downstream monthly mean concentrations. To assess temporal changes over time in both areas, linear and step changes in monthly mean concentrations among years for the upstream station will be evaluation by testing the hypothesis:

$$H_{02}: \mu_{RG\_KERRRD\_2014} = \mu_{RG\_KERRRD\_2015} = \ldots = \mu_{RG\_KERRRD\_n}$$

where $\mu_{RG\_KERRRD\_n}$ represents the monthly mean concentrations at RG_KERRRD in year n (final year of data). If a difference among years is detected (α = 0.05) then *post hoc* contrasts will be conducted to test for linear and step changes.

Upstream and downstream station comparisons will be conducted by testing whether differences in monthly mean concentrations between stations are different from zero using a

one-sample t-test (or Wilcoxon signed rank test when assumptions of normality are not met) by testing the hypothesis:

H_{03}: $\mu_d = 0$

Tests for H_{03} are conducted by pooling all years of data if differences in monthly mean concentrations between stations are not significantly different among years (i.e., H_{01} is not rejected) and are conducted by year if differences in monthly mean concentrations between stations are significantly different among years (i.e., H_{01} is rejected).

The magnitude of difference (MOD) between stations is calculated if a significant difference is detected between stations as (using RG_USGOLD as an example):

$$\text{MOD} = \frac{(MCT_{RG\_USGOLD} - MCT_{RG\_KERRRD})}{MCT_{RG\_KERRRD}} \times 100\%$$

where MCT_{RG_USGOLD} and MCT_{RG_KERRRD} are the measure of central tendency (MCT) for the downstream and upstream stations, respectfully (i.e., mean or median depending on whether the statistical comparison is conducted using a parametric or non-parametric method, respectively). The MOD for the temporal analyses will be calculated for linear trends as:

$$\text{MOD} = \frac{(Fitted_{RG\_USGOLD} - Pred_{RG\_USGOLD})}{Pred_{RG\_USGOLD}} \times 100\%$$

where $Fitted_{RG\_USGOLD}$ is the fitted mean value for the downstream station in the final year and $Pred_{DS}$ is the predicted mean value for the mine-exposed station in the final year, assuming that the slope of the downstream station is the same as the slope of the upstream station. The MOD will be calculated for step changes as:

$$\text{MOD} = \frac{(OBSPostStep_{RG\_USGOLD} - PredPostStep_{RG\_USGOLD})}{PredPost\ Step_{RG\_USGOLD}} \times 100\%$$

where $OBSPostStep_{RG\_USGOLD}$ is the observed mean for the downstream station after the step change and $PredPostStep_{RG\_USGOLD}$ is the predicted mean for the downstream station after the step change assuming that the relative difference between downstream and upstream stations after the step change is the same as the difference observed prior to the step change. The means will be anti-logged (if a $\log_{10}$-transformation is used) prior to calculating the MOD to put the concentrations in the original data units. Statistical analyses will be conducted using R statistical software (R Core Team 2015).

3.2.6 Elk River Mixing into Koocanusa Reservoir Assessment

A conductivity-based assessment of mixing of the Elk River in Koocanusa Reservoir will be completed using a CTD[12] device at low reservoir levels (late April), intermediate levels (late May/early June), and at full pool (late August) (Figure 1.2). Based on input from the EMC meeting on February 21, 2018, there are concerns that the Elk River is not fully mixed within the reservoir at the downstream sampling area (RG_DSELK), and that the Elk River may be influencing water quality at the upstream sampling area (RG_KERRRD). Specific conductance is generally higher (average 77 µS/cm higher) in the Elk River (RG_ELKMOUTH) compared to the Kootenay River (RG_WARDB) based on data from 2014 to 2016 (Figure 3.2). The difference between specific conductance measurements in these inflows will be used to track mixing of the Elk River as it flows into the reservoir.

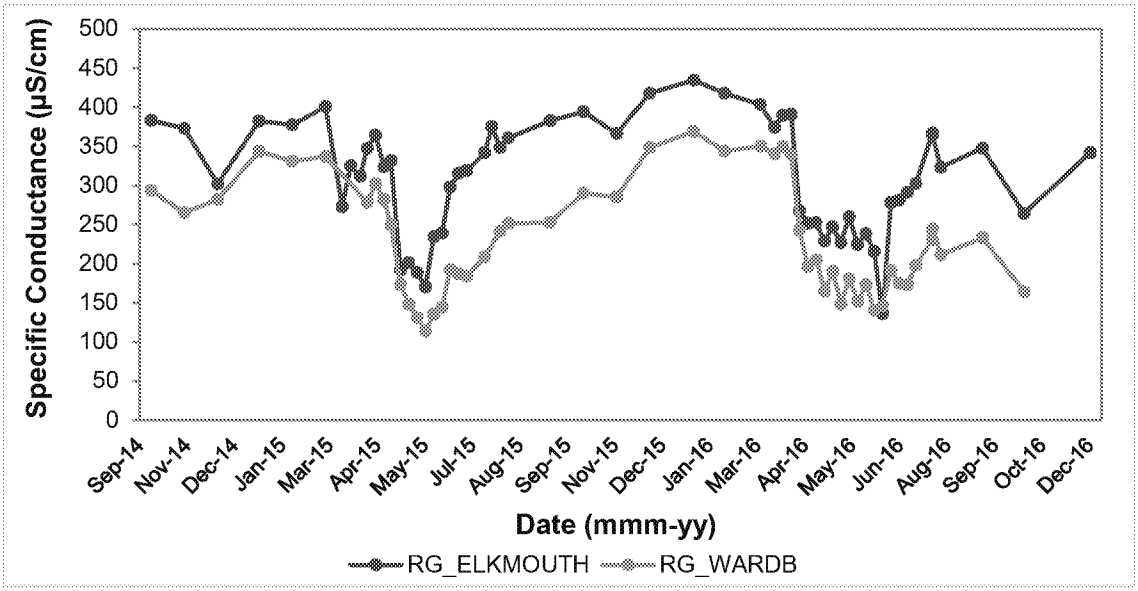


Figure 3.2: Specific Conductance in the Kootenay River (RG_WARDB) and the Elk River (RG_ELKMOUTH), 2014 to 2016

A CTD device will be used to measure conductivity and temperature with respect to depth. In addition, the CTD will be equipped with a Geographic Positioning System (GPS) with high memory availability for data logging capabilities. To collect profile data, the CTD will be lowered from a boat, and conductivity, temperature, and pressure will be recorded. The pressure parameter is converted to depth directly by the CTD using the density of water (calculated based on temperature and salinity).

[12] CTD stands for conductivity, temperature, and depth.

Water levels in the spring are very low in Koocanusa Reservoir compared to summer (Figure 1.2), so the location of CTD transects taken in April and June will vary from August transects (Figure 3.3). Initially, a conductivity measurement will be taken at RG_ELKMOUTH (Figure 3.3) to determine conductivity in the Elk River prior to entering the reservoir. Five transects consisting of five evenly-spaced CTD profiles along each transect will be taken upstream of the Elk River confluence (Figure 3.3). At the confluence of the Elk River to the reservoir (which will be different in April and June compared to August), CTD profile transects will initially be closely grouped (i.e., every 250 m, up to 1,000 m from the inlet), and will consist of five evenly-spaced profiles (Figure 3.3). After 1,000 m, the transects will be spaced further apart (e.g., every 1000 m; Figure 3.3). Based on the specific conductance data, Elk River concentrations at each logged location downstream of the inlet will be calculated using the following equation:

$$\% \text{ Elk River Concentration} = \frac{SCmeasured - SCupstream\ of\ Elk\ River}{SCElk\ River - SCupstream\ of\ Elk\ River}$$

where, $SC_{measured}$ = specific conductance at the individual location;

$SC_{upstream\ of\ Elk\ River}$ = average background specific conductance at a specific depth;

and

$SC_{Elk\ River}$ = average specific conductance of the Elk River

Calculated percent Elk River values will be categorized into ranges (>2.5%, 1.0 - 2.5%, 0.5 - 1.0%, and 0 - 0.5%), and will be mapped using GIS software.

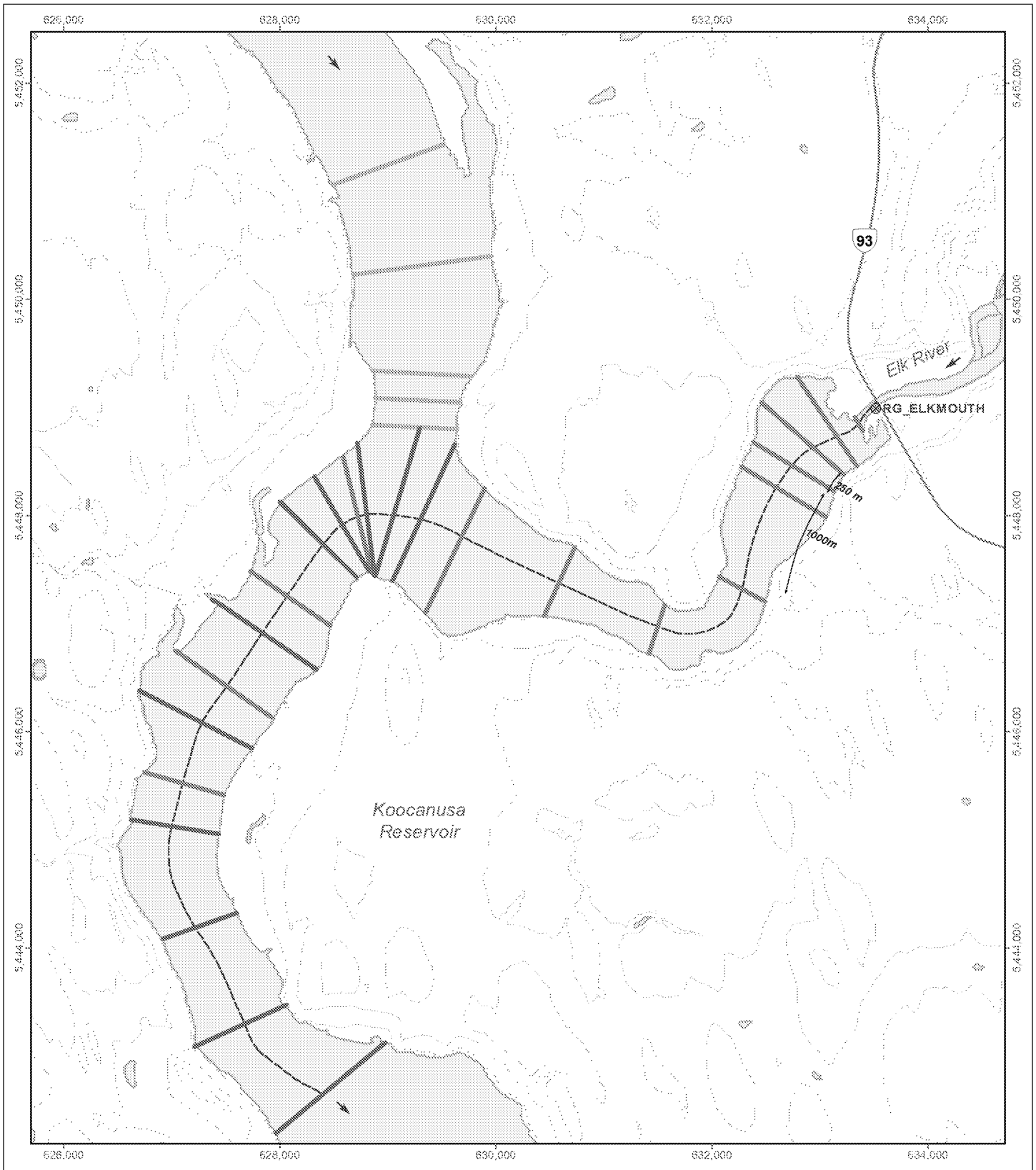
3.3 Sediment Quality

3.3.1 Overview

Sediment quality will be assessed during the 2018 to 2020 monitoring period to provide supporting data for the biological component of the study. Consistent with the 2014 to 2016 monitoring program, sediment quality samples will be collected annually in August from 2018 to 2020. Sediment sampling will occur at stations upstream and downstream of the Elk River. In addition, sediment samples will be collected in April 2018, concurrent and co-located with littoral benthic invertebrate tissue samples (Figure 3.1; Table 3.2).

3.3.2 Sample Collection

Sediment samples for physical and chemical characterization will be collected using a stainless steel Petite Ponar (0.023 m^2 sampling area). At each of the five stations downstream (RG_T4-1 to 5) and upstream of the Elk River (RG_TN-1 to 5), three grabs will be collected to create a



LEGEND

- August CTD Profile Transect
- April/June CTD Profile Transect
- CTD Profile Transect Upstream of the Elk River
- Transect Center Line
- Water Quality Station

Approximate Locations of CTD Transects for the Elk River Mixing Study in Koocanusa Reservoir, 2018

0 0.75 1.5 3 km

N W E S

Projection: North American Datum 1983 UTM Zone 11

Date: April 2018
Project 177202.0048

minnow environmental inc.

Figure 3.3

Document Path: S:\Projects\177202\177202.0048 - Teck Koocanusa 2017\Mapping\Study Design\7-48 Fig 3.3 Mixing Study in Koocanusa Reservoir, 2018.mxd

composite sediment sample consisting of the top three centimetres (cm) of sediment (i.e., the sediment fraction in which most benthic fauna generally reside [Kirchner 1975]). Following retrieval of each grab, the ponar will be gently opened and lifted to release the collected sediment into a clean plastic tub. If the grab is not complete to each edge of the ponar, or lacks an intact sediment-water surface layer, it will be discarded and a new grab collected. If the grab is acceptable, the top three cm will be removed and placed into a separate plastic tub. The procedure will be repeated until three acceptable grabs are obtained, after which the sample will be homogenized using a stainless steel spoon. The homogenized sediment will then be transferred to a glass jar (for analysis of polycyclic aromatic hydrocarbons [PAHs]) and a large labelled polyethylene bag (for other analyses, as described below). Samples will be placed in a cooler with ice and transferred to a refrigerator later in the day before submission to a Canadian Association for Laboratory Accreditation Inc. (CALA) accredited laboratory (e.g., ALS Environmental in Calgary, Alberta) for analysis.

Littoral sediment samples will be collected using a stainless steel Petite Ponar grab sampler (0.023 m^2 sampling area) or a stainless steel spoon, depending on the sampling conditions in each area. Sampling will occur in April 2018 (concurrent with fish sampling) and five stations will be sampled throughout the three sampling areas (Sand Creek, Elk River, and Gold Creek; Figure 3.1). If the Petite Ponar sampling is effective, sediment samples will be collected similarly to samples collected at the upstream and downstream stations (above) with three grabs composited at each station. If samples can only be collected by stainless steel spoon, the sample will be collected on shore, directly above the water surface, ensuring that only the top 3 cm of sediment are collected. A minimum of five full spoon scoops will be composited together in a clean white tub and the sample will be homogenized before transferring to a glass jar and polyethylene bag for laboratory analysis.

3.3.3 Laboratory Analysis

Sediment samples (whole sample not field-sieved) will be sent to an accredited laboratory for analysis of PAHs, moisture content, particle size, TOC, and metals/metalloids (hereafter collectively referred to as metals), consistent with ENV laboratory guidance manual as specified in Permit 107517 (Province of BC 2015).

Sediment sampling quality assurance/quality control (QA/QC) will include the collection and analysis of duplicate samples (a minimum of 10%), as well as an assessment of the accuracy and precision of laboratory data (Province of BC 2013, 2015). Data quality will be judged based on the ability to achieve minimum LRLs (Table 3.3), and results of laboratory duplicates, spike recovery samples, blank samples, and CRMs (see Section 4).

3.3.4 Data Analysis

Results from the data analysis will be used to address the following question:

- Are concentrations of mine-related constituents in sediment that benthic invertebrates are exposed to different downstream of the Elk River compared to upstream and are concentrations changing over time?

Sediment particle size distribution will be plotted using a stacked bar graph with concentrations of TOC plotted on a secondary axis. Sediment chemistry data (from downstream and upstream of the Elk River, and the littoral areas [Sand Creek, Elk River, and Gold Creek]) will be compared to applicable BC Working Sediment Quality Guidelines (WSQGs) and parameters with mean concentrations that exceed the lowest WSQG (and selenium) will be plotted. The lower WSQGs (i.e., lowest effect level/threshold effect level – LEL/TEL) represent concentrations below which adverse biological effects would not be expected to occur (BCMOE 2017b). In contrast, the highest sediment quality guidelines (i.e., probable effect level/severe effect level – PEL/SEL) represent concentrations above which effects may be observed (BCMOE 2017b).

For mean sediment concentrations of parameters collected annually, a two-way ANOVA with factors *Area* and *Year* will be used to compare areas located downstream versus upstream of the Elk River throughout the second cycle monitoring study (2018 to 2020). Results will also be compared to the first monitoring cycle (2014 to 2016). It was determined that sampling area T2 was potentially influenced by the Elk River so data collected from this area in 2014 will be omitted from the data analysis. Contrasts will be conducted after the two-way ANOVA to assess temporal changes (linear and step changes) in the relative difference between downstream and upstream concentrations (equivalent to H_{01} in Section 3.2.5). If the interaction between *Area* and *Year* is not significant in the two-way ANOVA, the *Area* and *Year* effects will also be assessed (similar to H_{03} and H_{02} in Section 3.2.5, respectively). If the interaction between *Area* and *Year* is significant, then the conclusion will be that there is a difference between areas, but the difference depends on the year. Spatial comparisons will then be conducted between areas separately by year. Assumptions of normality and homogeneity of variances will be tested on residuals of the two-way ANOVA using the Shapiro-Wilks' and Levene's tests, respectfully. Data will be $\log_{10}$-transformed as required to meet assumptions. If assumptions are not met, a rank transformation will be used. A more liberal α of 0.01 will be used for testing the assumptions to limit the use of the rank transformation to those instances where assumptions are violated.

The MOD will be calculated in two ways. First, a magnitude of difference will be reported for the comparisons between areas (either pooled across years or separately by year) as a standardized difference in terms of the number of within-area/year standard deviations as:

$$\text{MOD} = \frac{(\bar{X}_{RG\_T4} - \bar{X}_{RG\_TN})}{S_r}$$

where $\bar{X}_{RG\_T4}$ is the mean for the downstream area, $\bar{X}_{RG\_TN}$ is the mean for the upstream area, and S_r is the pooled standard deviation of the residuals (i.e., the within-area/year standard deviation) of the two-way ANOVA model.

Second, a MOD will also be reported for the comparisons between areas (either pooled across years or separately by year) as a percentage difference in the measure of central tendency between areas relative to the upstream area as:

$$\text{MOD} = \frac{(MCT_{RG\_T4} - MCT_{RG\_TN})}{MCT_{RG\_TN}} \times 100\%$$

where MCT_{RG_T4} and MCT_{RG_TN} are the measures of central tendency for the downstream and upstream areas. Measures of central tendency will be reported in the original data units as:

- means when no transformation is used;
- geometric means when a $\log_{10}$-transformation is used; and
- medians when a rank transformation is used.

The MOD for temporal analyses will be calculated as described in Section 3.2.5. An ANOVA will be used to evaluate differences in sediment chemistry among littoral areas. The two downstream areas (Elk River and Gold Creek) will be compared to the upstream area (Sand Creek) in 2018.

3.4 Plankton

3.4.1 Overview

Phytoplankton and zooplankton are an essential component of the reservoir's ecosystem and food chain (Lotic 2017). Phytoplankton are the base of the aquatic food chain, essential for primary production. Phytoplankton biomass can provide an indication of trophic status of the reservoir. Zooplankton are a valuable food source for planktivorous fish and other organisms. Phytoplankton and zooplankton community data will be collected in 2018 both upstream and downstream of the Elk River (Figure 3.1, Table 3.2). Zooplankton tissue will be collected annually (2018 to 2020) from the same stations as community samples (Figure 3.1).

3.4.2 Sample Collection

3.4.2.1 Community Composition

Samples for analysis of phytoplankton community structure will be collected as depth-integrated samples through the top 10 m of the water column from five stations upstream and downstream of the Elk River (RG_TN-1 to RG_TN-5 and RG_T4-1 to RG_T4-5; Figure 3.1), in August 2018. Depth-integrated water samples will be collected by lowering a 1 cm inside-diameter plastic tube, equipped with a weight, to a depth of 10 m (approximate photic zone) and, after crimping the tube to prevent water loss upon retrieval, the tube will be pulled to the surface and water inside the tube emptied directly into a clean pail and mixed. A total of three grabs will be composited to form a sample. A 100 mL sample will be taken and Lugol's solution will be added to the sample for preservation (enough volume to darken the solution to a weak tea colour). The sample will be mixed with the Lugol's solution by gently tipping the jar twice. Samples will be maintained at room temperature until shipment to a qualified laboratory for analysis (e.g., Plankton R Us, Winnipeg, Manitoba).

Samples for analysis of zooplankton community composition will be collected using a 19 cm diameter, fine mesh (i.e., 60 µm) plankton net, vertically hauled through the entire water column at each sampling station, based on methods described by Province of BC (2013). The plankton net will be lowered to a depth of 1.5 m from the sediment-water interface (to avoid disturbing the sediment, potentially resulting in addition of benthic organisms to the sample). A total of three vertical hauls will be collected and composited to form a single community sample at each of the sampling stations at RG_TN (RG_TN-1 to RG_TN-5) and RG_T4 (RG_T4-1 to RG_T4-5). Each sample will be transferred into a pre-labelled plastic sampling jar, and preserved to a level of 10% buffered formalin. Samples will be maintained at room temperature until shipment to a qualified laboratory for taxonomic identification (e.g., Salki Consultant Inc. in Winnipeg, Manitoba).

3.4.2.2 Tissue Chemistry

Zooplankton will be collected for analysis of tissue chemistry using an 80 µm mesh net (30 cm diameter) vertically hauled through the entire water column (as described in Section 3.4.2.1) and vertically hauled through the top 10 m of the water column (i.e., two separate samples). A slightly larger mesh size will be used for tissue collection so that the sample mostly consists of zooplankton and is not confounded by the presence of phytoplankton. A total of 10 vertical hauls will be collected at each station (i.e., RG_TN-1 to RG_TN-5 and RG_T4-1 to RG_T4-5) for samples collected through the entire water column, and samples collected through the top 10 m. Hauls will be composited and filtered through the net a second time to remove as much water

as possible, and to allow for sufficient sample weight for analysis. Samples will then be transferred to sterile cryovials and frozen, pending shipment to a CALA accredited laboratory (e.g., SRC in Saskatoon, Saskatchewan), consistent with ENV laboratory guidance as specified in Permit 107517 (Province of BC 2015).

3.4.3 Laboratory Analysis

3.4.3.1 Community

For phytoplankton samples, 10 mL aliquots of preserved sample will first be gravity settled for 24 hours. Cell counts will be performed using the Ütermohl technique as modified by Nauwerck (1963), using an inverted microscope at magnifications of 125×, 400×, and 1200× with phase contrast illumination. Specimens will be identified to the lowest taxonomic level possible. Cell counts will be converted to wet weight biomass by approximating cell volume. Estimates of cell volume for each species will be obtained by measuring up to 50 cells of an individual species and applying the geometric formula best fitted to the shape of the cell (Vollenweider 1968; Rott 1981). A specific gravity of 1 will be assumed for cellular mass.

Zooplankton samples, after standing for 72 hours, will be decanted (60 µm filter on vacuum hose, back flushed) to 45 mL glass vials to standardize volume (40 mL) for analyses and long term storage. Samples will be analyzed for species composition, abundance, and biomass of crustaceans and rotifers. Each sample will undergo the following three levels of analysis:

- 1/10, 1/20, 1/40 or 1/80 (depending on amount of zooplankton in sample) of each sample will be examined under a compound microscope at 63× to 160×, and a minimum of 200 organisms will be identified to species (crustaceans) or lowest possible level (rotifers), and assigned to instar size categories. Additionally, lengths (± 15 µm) of female and male adult specimens (n=20) of dominant species will be measured in representative samples for biomass determinations;
- a sub-sample, representing 10 to 20% of the sample volume, will be examined under a stereoscope at 12× magnification for mature and gravid individuals of larger species, and for individuals of less abundant species. They will be identified, enumerated, and assigned to size classes; and
- the entire sample will be examined under stereoscope to improve abundance/biomass estimates for the largest, less numerous species.

Under a compound microscope, Cyclopoida and Calanoida specimens (mature and immature) will be identified to the species level, with the exception of nauplii (N1-N6) which will be classified as either Calanoida (small or large) or Cyclopoida (small or large). Cladocera will be

identified to the species level, while rotifers will be identified to genus. Zooplankton abundance will be reported as individuals per litre (ind/L) based on volumes calculated from net mouth area and sample haul depth. Taxonomic identifications are based primarily on Brooks (1957), Wilson (1959), and Yeatman (1959).

Biomass estimates for each species will be determined from:

- abundances of adults multiplied by mean adult wet weights developed from measured lengths (n=20 per adults of dominant species in representative samples), and length-weight relationships from Malley et al. (1989); and
- abundances of various immature instar categories multiplied by weights of respective size categories determined from length-weight regressions (Malley et al. 1989).

Additional size measurements are made on less common specimens for biomass calculations. Zooplankton biomass is reported in micrograms (wet weight) per litre (µg/L). Digital microscopic images of selected specimens are provided with the analytical data.

For both phytoplankton and zooplankton community samples, sub-sampling accuracy will be assessed by performing replicate counts on 10% of samples (in this case, one sample each of phytoplankton and zooplankton). Replicate samples will be chosen at random and processed at different times from the original sample to reduce bias.

3.4.3.2 Tissue Chemistry

Zooplankton samples will be promptly shipped to a qualified laboratory for analysis of metals (including mercury) and selenium using high-resolution inductively coupled plasma mass spectrometry (HR-ICP-MS). The laboratory will freeze dry the samples prior to analysis. Concentrations will be reported on a dry weight basis. Accuracy and precision of data will be judged based on ability to achieve minimum LRLs (Table 3.6), replicate analysis of a minimum of 10% of samples, as well as a comparison to CRMs.

3.4.4 Data Analysis

Results from the data analysis will be used to address the following questions:

- Do phytoplankton and/or zooplankton community structure differ downstream of the Elk River compared to upstream and are the differences changing over time?
- Are selenium concentrations in zooplankton different downstream of the Elk River compared to upstream, and are the differences changing over time?

Table 3.6: **Minimum Laboratory Reporting Limits (LRLs) for Tissue Samples**

Analyte	Units	Plankton, Benthic Invertebrate, and Fish Tissue LRL [a]
Moisture	%	-
Aluminum (Al)	µg/g dw	2
Antimony (Sb)	µg/g dw	0.1
Arsenic (As)	µg/g dw	0.05
Barium (Ba)	µg/g dw	0.05
Beryllium (Be)	µg/g dw	0.01
Boron (B)	µg/g dw	1
Cadmium (Cd)	µg/g dw	0.01
Chromium (Cr)	µg/g dw	0.5
Cobalt (Co)	µg/g dw	0.01
Copper (Cu)	µg/g dw	0.05
Iron (Fe)	µg/g dw	2
Lead (Pb)	µg/g dw	0.01
Manganese (Mn)	µg/g dw	0.1
Mercury (Hg)	µg/g dw	0.005
Molybdenum (Mo)	µg/g dw	0.1
Nickel (Ni)	µg/g dw	0.05
Selenium (Se)	µg/g dw	0.05
Silver (Ag)	µg/g dw	0.01
Strontium (Sr)	µg/g dw	0.1
Thallium (Tl)	µg/g dw	0.05
Tin (Sn)	µg/g dw	0.05
Titanium (Ti)	µg/g dw	0.05
Uranium (U)	µg/g dw	0.005
Vanadium (V)	µg/g dw	0.1
Zinc (Zn)	µg/g dw	0.5

[a] Laboratory reporting limits provided by SRC in Saskatoon, Saskatchewan.

3.4.4.1 Community

Phytoplankton and zooplankton will be evaluated between areas and over time using primary metrics of mean taxonomic richness [as identified to lowest practical level (LPL)], mean organism density (average number of cells or organisms per litre), and mean biomass (mass of cells or organisms per litre). Comparisons will be made based on absolute and relative density as well as absolute and relative biomass. Relative density and relative biomass will be calculated as the density or biomass of each respective taxa and group relative to the total number of cells or organisms in the sample for dominant taxa and groups. Dominant taxa will be defined as taxa representing at least 5% of the total cell or organism density at one or more stations. Community endpoints will be summarized by reporting the minimum, maximum, mean, median, standard deviation (SD), and sample size for each sampling area. Statistical comparisons will be based on differences in major taxonomic groups. A two-way ANOVA will be used to assess spatial and temporal differences in plankton community endpoints in the area downstream from the Elk River compared to the upstream area in 2018, and to results obtained from the first cycle 2014 to 2016, as described in Section 3.3.4. Results from the upstream area (T2) in 2014 will not be included in future analyses, as the area was potentially influenced by the Elk River (Minnow 2018b).

Non-metric multi-dimensional scaling (NMDS) will be used to respectively reduce phytoplankton and zooplankton taxonomic data matrices to fewer dimensions. NMDS is a method to visualize the level of similarity of samples based on the rank of the similarities (Clarke 1993). NMDS takes the N-dimensional (here N = number of taxa) coordinates of each sample (i.e., station in a given area/year) and defines a set of new n-dimensional coordinates that reflect the locations (rank distances) among samples. The n = 2 dimension is frequently used because the sample stations can be plotted on a 2-dimensional scatterplot.

The NMDS will be conducted using the Bray-Curtis distance as the measure of relative community similarity or dissimilarity using PC-ORD© software (McCune and Mefford 2011). Taxa occurring in fewer than 5% of the samples will be removed from the dataset as their exclusion from multivariate analyses reduces 'noise' (Bailey et al. 2004). The 'slow and thorough' option, which uses the following settings, will be applied: maximum iterations = 400, instability criterion = 0.00001, number of real runs = 40, and number of randomized runs = 50 (McCune and Grace 2002). NMDS ordinations will be evaluated for solution stability, final stress <0.2, and Monte Carlo randomized determination of interpretable axes of $p < 0.05$ (McCune and Grace 2002).

NMDS of non-transformed data often results in "shallow interpretation in which only the pattern of a few, very common species is represented" (Clarke 1993). Thus, a suite of transformations

will be applied (log_{10}, square root, 4th root, power 2, and power 4) which assigns different weights to the less common taxa, relative to abundant taxa (Clarke 1993). The suite of transformations will be evaluated because it is not known *a priori* which transformation would best explain the differences in community structure (i.e., the appropriate weight to assign to rare taxa relative to abundant taxa). Results will be reported for transformations that have mean skew and kurtosis values closest to zero. The NMDS analyses will be conducted using absolute abundance taxa data matrices at LPL. The 2- or 3-dimensional ordination will be selected based on PC-ORD© decision criteria (final stress less than 0.2, randomization test with $p < 0.05$, and a reduction of at least 5 points of stress with each additional axis). Statistical comparisons of NMDS axes will be used to assess differences in community structures between areas and over time using a two-way ANOVA, as described in Section 3.3.4.

3.4.4.2 Tissue Chemistry

Concentrations of selenium will be compared to the interim BC guideline for invertebrate tissue (4 µg/g dw), EVWQP Level 1 benchmarks for effects to benthic invertebrates (13 µg/g dw), and dietary effects to juvenile fish (11 µg/g dw).

Selenium concentrations in zooplankton found using the two different collection methods (i.e., sampling entire water column or the top 10 m of water column) will be plotted using individual value plots and compared statistically using a paired t-test. If results are statistically different between sampling methods, only the results from sampling the top 10 m will be compared to the zooplankton selenium concentrations from the 2014 to 2016 monitoring program (Minnow 2018). If results are not significantly different, results from both methods will be compared to the previous monitoring program. Selenium concentrations in zooplankton will also be compared statistically between the downstream area (RG_T4) and the upstream area (RG_TN) for each of the study years (2018 to 2020) using both methods, using a two-way ANOVA as described in Section 3.3.4.

3.5 Benthic Invertebrates

3.5.1 Overview

Benthic invertebrates are an essential component of a waterbody's ecosystem and food chain, providing a valuable food source for benthivorous fish (Covich et al 1999). Benthic invertebrate community samples will be collected in August 2018 at the five stations located upstream and downstream of the Elk River (Table 3.2). Benthic invertebrate tissue samples will be collected twice annually in the 2018 to 2020 monitoring program (April and August) with samples collected in the same areas as community samples, both upstream and downstream of the Elk

River. In addition, littoral benthic invertebrate tissue samples will be collected in from the Sand Creek, Elk River, and Gold Creek areas in April 2018.

3.5.2 Sample Collection

3.5.2.1 Community

Consistent with the 2014 to 2016 study, benthic invertebrate community sampling will be completed at each of five stations upstream and downstream from the Elk River (i.e., RG_TN-1 to RG_TN-5 and RG_T4-1 to RG_T4-5, respectively; Figure 3.1) in August 2018, when water levels are most stable and benthic invertebrate communities are anticipated to be at peak biomass and diversity (BCMOE 2006). Benthic invertebrate community samples will be collected using a stainless steel Petite Ponar sampler. A single sample, consisting of a composite of five Petite Ponar grabs, will be collected at each station with care taken so that each grab captures the surface material and is full to each edge. Incomplete grabs will be discarded. Each acceptable grab will be field-sieved using 500 µm mesh with the retained material carefully transferred into a plastic sampling jar containing both external and internal station identification labels. Benthic invertebrate samples will be preserved to a level of 10% buffered formalin in ambient water and submitted to a certified benthic taxonomist (e.g., Zeas Inc. in Nobleton, Ontario) for analysis.

3.5.2.2 Tissue Chemistry

A single composite benthic invertebrate tissue sample will be collected upstream and downstream of the Elk River in April and August of 2018 to 2020. A total of 20 Petite Ponar grabs (four from each of the five sampling stations [RG_TN-1 to RG_TN-5 and RG_T4-1 to RG_T4-5] in each study area) will be collected to obtain a single sample. Each grab will be placed into a 500 µm mesh sieve bag and sieved free of material less than 500 µm in size. The remaining material will be transferred to a white enamel tray for removal of benthic organisms using tweezers. Visible organisms will be removed from the debris/sediment and rinsed clean using ambient water. Similar to sampling conducted in 2014 to 2016, chironomids will be targeted for tissue collection, but if chironomids are not present in sufficient numbers, other benthic invertebrates will be added to the sample (and noted on field sheets) to achieve sufficient sample weight for analysis (approximately 0.5 g).

Benthic invertebrates will also be collected in April 2018 along the shoreline margins, at the Sand Creek, Elk River, and Gold Creek sampling areas (n = 5 samples per area). Samples will be collected with a kick net having a triangular aperture measuring 36 cm per side and 400 µm mesh (net recommended for the CABIN protocol). The net will be swept back and forth along the shoreline to collect benthic invertebrates. The kick-net will be rinsed with water to move

debris and invertebrates into the collection cup at the bottom of the net. The sample will be transferred to a white enamel tray and organisms will be removed from the debris using tweezers until a minimum of 0.5 g of tissue is obtained for analysis.

3.5.3 Laboratory Analysis

3.5.3.1 Community

Benthic invertebrate community analysis will follow standard sorting methods which incorporate recommended QA/QC procedures for assessing sub-sampling error and sorting recovery checks (Environment Canada 2012a). Upon arrival at the laboratory, a biological stain will be added to each sample to facilitate greater sorting accuracy. Samples will be washed free of formalin in a 500 µm sieve and examined under a stereomicroscope at a magnification of at least ten times. Benthic invertebrates will be removed from the sample debris and placed into vials containing a 70% ethanol solution according to major taxonomic groups (e.g., phyla, orders). A senior taxonomist will enumerate and identify benthic organisms to the lowest practical level (typically to genus or species) using the most recent taxonomic keys. Following identification, representative specimens of new taxa will be preserved in a 75% ethanol, 3% glycerol solution in separately labelled vials and added to the voucher collection for the project.

3.5.3.2 Tissue Chemistry

Benthic invertebrate tissue samples will be promptly shipped to a qualified laboratory for analysis of metals (including mercury) and selenium using HR-ICP-MS. The laboratory will freeze dry the samples prior to analysis. Concentrations will be reported on a dry weight basis, along with moisture content to allow conversion to wet weight values, as required. Accuracy and precision of laboratory data will be judged based on ability to achieve minimum LRLs (Table 3.6), as well as replicate analysis (minimum of 10% of samples) and comparison to CRMs.

3.5.4 Data Analysis

Results from the data analysis will be used to address the following questions:

- Are selenium concentrations in benthic invertebrates greater than guidelines or effect thresholds, do they differ downstream of the Elk River compared to upstream, and are the differences changing over time?
- Does benthic invertebrate community structure differ downstream of the Elk River compared to upstream, and are the differences changing over time?

Benthic invertebrate communities will be evaluated between areas and over time similar to plankton communities (Section 3.4.4). Primary metrics of mean taxonomic richness (as identified to LPL) and mean organism density (average number of organisms per m^2) will be calculated. Absolute and relative densities (calculated as the density of each respective taxa and group relative to the total number of organisms in the sample) of dominant taxa and groups will also be calculated. Dominant taxa will be defined as those species representing at least 5% of the total organism density at one or more stations. Community endpoints will be summarized by reporting the mean, median, minimum, maximum, SD, and sample size for each sampling area and year.

A two-way ANOVA will be used to assess spatial and temporal differences in benthic invertebrate community endpoints in the area downstream from the Elk River compared to the upstream area, and will incorporate relevant data from the 2014 to 2016 monitoring program, as described in Section 3.3.4.

Benthic invertebrate communities will also be assessed using NMDS as described in Section 3.4.4.

Selenium concentrations from 2018 to 2020 will be compared between the downstream area and the upstream area, and will incorporate relevant data from the 2014 to 2016 monitoring program, using a two-way ANOVA as described in Section 3.4.4. An ANOVA will also be used to evaluate differences between selenium concentrations in benthic invertebrates from littoral areas. The two downstream areas (Elk River and Gold Creek) will be compared to the upstream area (Sand Creek) in 2018. Selenium concentrations in benthic invertebrates will also be plotted and compared to the BCMOE (2017a) interim guideline of 4 µg/g dw and the Level 1 benchmarks (Teck 2014) from the EVWQP (i.e., 13 and 11 µg/g dw for effects on benthic invertebrate reproduction and for dietary effects to fish, respectively).

3.6 Fish

3.6.1 Overview

Collection of fish will be an integral component of the Koocanusa Reservoir monitoring program (Table 3.2). Fish represent the highest trophic level in the reservoir and are an important resource for human consumption (Lotic 2017, Ramboll Environ 2016). Fish tissue sampling in the reservoir will include collection of sport fish (e.g., bull trout) muscle using non-lethal methods (i.e., muscle plug). Peamouth chub, redside shiner, and northern pikeminnow will also be sampled for muscle and ovary tissue chemistry.

Fish health surveys completed in the 2014 to 2016 monitoring study showed no consistent patterns in fish health endpoints among fish species, sexes, or sampling years that were

indicative of influence from the Elk River. Since the previous fish health survey showed very little consistencies, the 2018 fish health assessment will focus on peamouth chub and redside shiners, which represent species that have been sampled in the past, and can be collected with relative ease in ripe spawning condition (required for reproductive health endpoints). Peamouth chub and redside shiner will be collected near the mouths of Sand Creek, the Elk River, and Gold Creek in spring (April), prior to spawning in 2018. These species also represent a food source for piscivorous fish (Lotic 2017).

Redside shiner, which had the highest ovary mean selenium concentrations in the 2014 to 2016 monitoring program (Minnow 2018b) will be the focal species for assessment of recruitment (requested and supported by the EMC). Recruitment will be assessed annually in August at each of the three fishing areas to confirm the presence of young-of-the-year (YOY) redside shiner, among other endpoints (Table 3.1).

3.6.2 Sample Collection

3.6.2.1 Fish Tissue

The targeted species, the number of samples collected, and the timing of collection for the fish tissue chemistry assessment will be as follows:

- sport fish muscle (non-lethal muscle plugs) collection from up to eight individuals per species in each of the three fishing areas in 2018 (Figure 3.1);
- peamouth chub and redside shiner ovary and muscle collection from up to 10 females per study area in April 2018 to 2020 (collected in 2018 as part of the fish health assessment). These species were targeted in the 2014 to 2016 monitoring cycle and both had mean selenium concentrations in ovaries above the BC guideline; and
- northern pikeminnow ovary and muscle collection from up to 10 females per fishing area in late May or early June 2018. Northern pikeminnow will be collected in May or June rather than April (as per the 2014 to 2016 program) to determine if average ovary selenium concentrations above the Level 1 benchmark for effects to fish reproduction observed in 2014 were potentially a result of pikeminnow having undeveloped ovaries (i.e., GSI <1 %).

The sport fish collection will target species previously collected in Koocanusa Reservoir (i.e., bull trout, kokanee, mountain whitefish, rainbow trout, westslope cutthroat trout, and yellow perch; Minnow 2018b). Burbot will not be a target species for muscle sampling based on

concerns about burbot abundance[13] and the cultural importance of this fish species to the KNC. If burbot are caught, they will be immediately released.

Fish will be collected using multiple methods. Very short-set gill nets (starting with a maximum set time of 15 minutes) will be used to avoid fish mortalities, as per Section 3.6.2.2 (below). Three foot-diameter hoop nets will also be deployed (effective for catching yellow perch; Minnow 2018b). Leads will be attached to the opening of each net and typically set perpendicular to shore. In strong flow areas, the mouth of the net will be directed downstream to minimize clogging from debris. The lead and net will be secured with anchors, and floats attached to the net to mark the location on the water surface. Hoop nets will be left to fish overnight (i.e., approximately 24 hours). Yellow perch will be sacrificed as they were inadvertently introduced into Koocanusa Reservoir (Huston et al. 1984; Hamilton et al. 1990), and the Ministry of Forests, Lands, Natural Resource Operations, and Rural Development (FLNRO) has requested that perch collected during sampling be sacrificed (FLNRO 2018). Angling will be used to target sport fish and supplement catches of other species, such as northern pikeminnow. Angling will be conducted from a boat using a single hook baited with salted salmon roe or worms, or with fishing lures. The location (UTMs) of each net set or angling site, as well as the time of deployment and the time of retrieval, will be recorded on field sheets. In addition, fish that are collected during the Montana Fish and Wildlife Program sampling on the Canadian side of Koocanusa Reservoir may be sampled to augment samples sizes.

For collection of tissues from fish that will be sacrificed (i.e., peamouth chub, northern pikeminnow, redside shiner, and yellow perch), methods will be consistent with those described in Section 3.6.2.2 (below). For fish being sampled non-lethally (i.e., most sport fish), fish will be lightly anaesthetized in a dilute clove oil solution prior to processing. Each fish will then be weighed using appropriately-sized spring scales, near the top of the scale's range to so that measurements achieve resolution of approximately one percent or less. Total length and fork length will be determined using a measuring board equipped with a metre stick (± 1 mm). External deformities, erosions (fin and gill), lesions, or tumours observed (i.e., DELT survey; Sanders et al. 1999) will be recorded on field sheets. A muscle sample will be collected using a biopsy punch (4 mm acu-punch). Following extraction of the biopsy sample, skin will be removed from the sample using a scalpel and the remaining muscle placed into a sterile cryovial. Once each fish recovers from the anesthetic in a recovery bin, it will be released back into the reservoir near its capture location.

[13] In recent years, lower Kootenay burbot populations were designated as critically imperiled and red-listed, meaning potentially extirpated, endangered, or threatened (BCMOE 2015)

Samples will be stored frozen pending shipment to the laboratory for analysis.

3.6.2.2 Fish Population Health

An *a priori* power analysis was completed to determine sample sizes required to detect a difference of 20-30% in relative gonad size (standard EEM protocol; Environment Canada 2012a; Appendix B). For the fish health assessment, 20 sexually mature female and 35 male peamouth chub will be targeted in each of the three study areas (Figure 3.1) in April 2018 (i.e., immediately prior to spawning; Appendix B). The *a priori* power analysis indicated that more redside shiner (35 female and 45 males) would be required to detect a difference of 20-30% in relative gonad size in each of the three study areas (Appendix B). Redside shiners will be sampled at the same time as peamouth chub. Fish will be collected using very short-set gill nets (starting with a maximum set time of 15 minutes). Representatives from the Elk Valley Fish and Fish Habitat Committee (EVFFHC) attended the EMC meeting on January 23rd, 2018, where members indicated that if gill nets are requested, only small-mesh, short-set gill nets will be approved to avoid incidental mortalities of sport fish. This advice was followed in the application for the scientific fish collection permit submitted to the FLNRO.

Gill nets will be set on the bottom, and nets of the same length (i.e., 75' or 150') and mesh sizes (1", 1.5", 2", or 2.5") will be deployed in each fishing area for each species (mesh size used for targeting peamouth chub will be larger than that used for redside shiners). The location of each net set (UTM coordinates), as well as the time of deployment and the time of retrieval, will be recorded on field sheets. Peamouth chub and redside shiner will be transported to a dedicated field laboratory for processing as soon as possible following capture (i.e., within hours).

Peamouth chub and redside shiner will be sacrificed by a decisive blow to the head. Fork and total lengths will be measured to the nearest millimeter using a standard measuring board. Fish weights will be measured using appropriately-sized spring scales (e.g., 50 g, 100 g, and 300 g) or a digital balance (± 0.001 g). Each fish will be opened and the sex and/or sexual maturity recorded. Whole gonads and livers will be removed from each fish and weighed to the nearest milligram using an analytical balance with a surrounding draft shield. Whole ovaries and a skinless, boneless muscle fillet sample will be collected from each sexually mature female being retained for tissue analysis and placed in separately labelled, polyethylene (Whirl-Pak®) bags. Following these measures, age structures (i.e., otoliths) will be removed from each fish. Each age structure will be wrapped separately in waxed paper and placed inside a labelled envelope. Internal or external deformities, erosions (fin and gill), lesions, or tumours (DELT) observed during processing (Sanders et al. 1999) and parasites will be recorded on laboratory bench sheets. Samples (i.e., ovaries, muscle, and age structures) will be stored frozen pending shipment to the respective laboratory for analysis.

3.6.2.3 Fish Recruitment

A non-lethal sampling design will be used to investigate if redside shiner recruitment is occurring, and to evaluate condition (among other non-lethal Environmental Effects Monitoring [EEM] endpoints) of YOY shiners between areas downstream of the Elk River (Elk River and Gold Creek) relative to upstream (Sand Creek). Seining will be used in littoral areas in an attempt to collect YOY redside shiner in each of the three study areas (Figure 3.1). Upon retrieval of the net, captured fish will be identified, enumerated, and inspected for external abnormalities (i.e., DELT survey). Non-target fish will be released alive at the capture location. Captured redside shiner will be placed in aerated buckets of water and retained for processing (described below). Fish sampling will target a minimum of 100 YOY redside shiner from each fishing area. The recruitment assessment will focus on YOY versus non-YOY (mostly expected to be 1+ age category based on previous sampling; Minnow 2018b). If sufficient numbers of individual non-YOY age classes are captured (e.g., greater than 100 redside shiner), endpoints will be examined separately for each age class. Recorded supporting information will include duration of sampling effort, sampling depth, area/distance sampled, UTM coordinates, and habitat descriptions.

Fish will be lightly anaesthetized in a dilute clove oil solution prior to processing. Length (fork and total) will be measured to the nearest hundredth of a millimetre using digital calipers, and fresh body weight will be measured to the nearest milligram using an analytical balance with a repeatability (standard deviation) of ± 0.003 g. External deformities, erosions (fin and gill), lesions, or tumours observed during processing (i.e., DELT survey) will be recorded on field sheets. A maximum of ten redside shiners in each area of varying sizes will be sacrificed for collection of otoliths according to methods described in Section 3.6.2.2. With the exception of fish sacrificed for aging, fish will be placed into a recovery bucket following processing. Fish will subsequently be released near the point of capture following completion of sampling.

3.6.3 Laboratory Analysis

3.6.3.1 Fish Age

Fish tissues collected for age analysis will be submitted to a qualified laboratory for analysis (e.g., AAE Technical Services in Winnipeg, Manitoba). Otoliths will be prepared and read under a compound microscope using transmitted light. For each structure, the age and edge condition will be recorded along with a confidence rating for the age determination. For the purpose of QA/QC, approximately 10% of samples will be assessed by a second individual at the laboratory.

3.6.3.2 Tissue Chemistry

Fish tissue samples for chemical analysis will be submitted to a CALA accredited laboratory (e.g., SRC in Saskatoon, Saskatchewan), consistent with ENV laboratory guidance as specified in Permit 107517 (Province of BC 2015).

Samples will first be freeze-dried for determination of moisture content and then analyzed for metals (including mercury) using HR-ICP-MS. Results will be reported on a dw basis, along with moisture content (based on the difference between wet and freeze-dried sample weights) to allow conversion to wet-weight values. Accuracy and precision of data will be judged based on ability to achieve minimum LRLs (Table 3.6), replicate analysis of a minimum of 10% of samples, as well as a comparison to CRMs.

3.6.4 Data Analysis

Results from the data analysis will be used to address the following questions:

- Are selenium concentrations in fish tissue greater than guidelines or effect thresholds, do they differ downstream of the Elk River compared to upstream, and are the differences changing over time?
- Is fish health different downstream of the Elk River compared to upstream, and are differences in fish health endpoints changing over time?
- Are there differences in redside shiner recruitment downstream of the Elk River compared to upstream?

3.6.4.1 Tissue Chemistry

Selenium concentrations in fish tissues will be statistically compared between the downstream areas (Elk River and Gold Creek) and the upstream area (Sand Creek) using both current (2018 to 2020) and previous (2014 to 2016) results. A two-way ANOVA will be used to compare data as described in Section 3.3.4. Selenium concentrations in fish tissues will be also plotted and compared to the MOE (2017a) guidelines (for muscle [4 µg/g dw] and ovaries [11 µg/g dw]), the 2016 USEPA guidelines (for muscle [11.3 µg/g dw] and ovaries [15.1 µg/g dw]), and the EVWQP Level 1 benchmark for reproductive effects (ovary tissues only [18 mg/kg dw]). Mercury concentrations in fish muscle relative to length will be tested using a two-way ANCOVA with factors Area (downstream of the Elk River and upstream of the Elk River) and Year, following similar methods to those described in Section 3.3.4. Mercury concentrations in fish tissues will also be compared to the BC tissue residue guideline for the protection of wildlife (0.033 µg/g wet weight [ww]; BCMOE 2017a).

3.6.4.2 Health Assessment

Fish health endpoints representing four response categories, survival (mean age), growth (body weight-at-age, fork length-at-age), reproduction (gonad weight-at-body weight), and energy storage (body weight-at-fork length, liver weight-at-body weight), will be evaluated separately for males and females of peamouth chub and redside shiner collected in each study area (Table 3.1). These are the endpoints reported for fish health assessments conducted by Canadian metal mines to satisfy Environmental Effects Monitoring (EEM) requirements under the *Fisheries Act* (Environment Canada 2012a). Magnitudes of difference will be interpreted relative to commonly accepted Critical Effect Sizes (CES; Munkittrick et al. 2009; Environment Canada 2012a; Table 3.1).

Summary statistics including mean, median, minimum, maximum, standard deviation, standard error, and sample size will be calculated by study area and fish sex for summary endpoints of age, body weight, fork length, condition factor (K = body weight/[fork length]^3×100,000), gonadosomatic index (GSI = gonad weight/body weight×100), and liver-somatic index (LSI = liver weight/body weight×100). Statistical analyses of datasets from the fish health survey will be consistent with procedures outlined in the EEM technical guidance document (Environment Canada 2012a), including the use of "adjusted" body weights in statistical analyses (whole body weight less the gonad and liver weights). Fish with parasites (e.g., tapeworms) will not be used for the statistical analyses (fish health assessment), although a comparison of abnormalities between areas will be completed.

Differences in mean age between study areas will be compared using ANOVA. Other endpoints will be compared using analysis of covariance (ANCOVA). Prior to conducting the ANOVA or ANCOVA tests, data will be assessed for normality and homogeneity of variance, and log-transformed. Scatterplots of variable and covariate combinations will be examined to identify outliers, leverage values or other unusual data, to confirm there is adequate overlap of data between areas being compared, and that there is a linear relationship between the variable and the covariate.

The first step in the ANCOVA analysis is to determine whether the slopes of the regression lines for both test areas are equal. This is accomplished by testing for a significant interaction term (dependent × covariate) in the ANCOVA model. If the interaction term is significant (i.e., regression slopes not equal, $p<0.05$), two methods will be used to determine whether a full ANCOVA can proceed. In order of preference, these are 1) removal of influential points using Cook's distance and re-assessment of equality of slopes, and 2) coefficients of determination that consider slopes equal regardless of an interaction effect (Environment Canada 2012a). If both methods prove unacceptable, the magnitude of difference calculation will be estimated at

both the minimum and maximum overlap of covariates between test areas (Environment Canada 2012a). This results in a significant interaction effect (slopes are significantly different), but the calculation of the magnitude of difference at the minimum and maximum values of covariate overlap is not assigned statistical difference as it would for a full ANCOVA model. If the interaction term is not significant (i.e., homogeneous slopes between the two test populations), then the full ANCOVA model is run without the interaction term to test for differences in adjusted means between the two populations. The adjusted mean is then used as an estimate of the population mean based on the value of the covariate in the ANCOVA model.

For endpoints showing significant differences between areas, the magnitude of difference will be calculated as described by Environment Canada (2012a) using the mean (ANOVA), adjusted mean (ANCOVA with no significant interaction) or predicted values (ANCOVA with significant interaction). The anti-log of the mean, adjusted mean or predicted value will be used in the equations for endpoints that are $\log_{10}$-transformed. In addition, the magnitude of difference for ANCOVA with a significant interaction will be calculated for each of the minimum and maximum values of the covariate. The minimum detectable effect size will be calculated as a percent difference from the reference mean (using the observed sample sizes and $\alpha = \beta = 0.1$).

Differences in fish health endpoints among study years will be assessed by comparing the differences among areas that are observed in 2018 to the results summarized in Table 7.3 of the 2014 to 2016 monitoring report (Minnow 2018b) using both two-way ANOVAs and two-way ANCOVAs.

3.6.4.3 Recruitment Assessment

Initial data analysis for the redside shiner recruitment survey will include plotting size frequency distributions as described by Bonar (2002) and Gray et al. (2002), so that, together with age data, YOY can be distinguished from non-YOY. Fish health endpoints of fork length, fresh body weight, and Fulton's condition factor (body weight / fork length^3 x 10^5) will be summarized by separately reporting mean, median, minimum, maximum, standard deviation, standard error and sample size by size class (i.e., YOY and non-YOY) for each fishing area. These endpoints will be used as the basis for evaluating four response categories (survival, growth, reproduction, and energy storage; Table 3.1) according to the procedures outlined for a non-lethal, small-bodied fish assessment in EEM (Gray et al. 2002; Environment Canada 2012a).

Length-frequency distributions based on fork length measurements will be compared between each area downstream of the Elk River and the upstream area using a Kolmogorov-Smirnov (KS) test using the combined YOY and non-YOY data set. The proportion of YOY fish in each area will be compared using the chi-square test of independence (to test the hypothesis that the

proportion of YOY fish is independent of area). Mean length and body weight will be compared separately for YOY and non-YOY groups between the three fishing areas using ANOVA, with the data inspected for normality and homogeneity of variance before applying parametric statistical procedures. In cases where data do not meet the assumptions of ANOVA, the Mann-Whitney test will be used to test for differences between areas. Body weight at fork length (condition) will be compared using ANCOVA based on the same transformations, scatter plot evaluations, and tests as described in Section 3.6.4.2. Similarly, the magnitude of observed differences and the minimum detectable effect sizes will be calculated, and together with CES, compared as described in Section 3.6.4.2.

4 QUALITY ASSURANCE/QUALITY CONTROL

4.1 General Overview

The quality assurance plan includes a number of formal components and procedures outlined below that will be implemented to evaluate the quality and integrity of data produced by the 2018 to 2020 Koocanusa Reservoir monitoring program. Additional useful guidance can be found in the BC Field Sampling Manual (Province of BC 2013) and federal EEM guidance (Environment Canada 2012a).

4.2 Study Team Responsibilities and Training

4.2.1 Technical

Study personnel must be appropriately educated, trained, and experienced for their respective technical responsibilities, whether in the field, laboratory, or office. Study personnel may be required by Teck to provide proof of education level or professional qualifications (e.g., Registered Professional Biologist). Project personnel must be familiar with study design requirements and methods relevant to their project role.

There are no formal training/certification programs for the types of sampling that will be completed for the 2008 to 2020 Koocanusa Reservoir monitoring program. Therefore, training for the components of the Koocanusa Reservoir surveys will be the joint responsibility of Teck and its consultants. Teck will review the qualifications and experience of project personnel relative to their assigned responsibilities in advance of field programs. Field crews will have read and become familiarized with the BC Field Sampling Manual requirements and sampling procedures (Province of BC 2013).

4.2.2 Health and Safety

Safety is of primary importance. Members of the project team are expected to contribute toward healthy and safe work conditions by being familiar with and complying with applicable Health and Safety Procedures. Environment, Health, Safety, and Community (EHSC) work plans and Environmental Protection Work Plans (EPWPs) must be filed with Teck in advance of field work taking place at or near Teck's mining operations. In addition, a field level hazard assessment (FLHA) is expected to be completed daily prior to starting work. Proper training regarding potential work-related hazards is also important.

Prior to execution of field work, field personnel should also receive training/certification, as applicable, through a qualified organization for activities such as:

- First aid and Cardiopulmonary Resuscitation (CPR);

- Workplace Hazardous Materials Information System (WHMIS);
- Transport of Dangerous Goods
- Boat operation (i.e., pleasure craft operators certification);
- Swift water rescue;
- Ice rescue; and
- Bear awareness.

4.3 Consistency (Standard Operating Procedures)

Consistency is an important component of a quality management program. To minimize errors and to maintain comparability of data over time, standard operating procedures (SOPs) must be followed for sample collection methods, calibration, and maintenance of field instruments, and proper sample handling and laboratory sample submission procedures. Each SOP should describe, in detail, the routine procedures to be followed. Short-term deviations from specified methods that occur should be documented in field notes and conveyed as appropriate in the technical reports in which the data are presented

4.4 Data Quality Assurance and Quality Control

4.4.1 Definition of Terms

4.4.1.1 General

Although the general intent and process for data quality assurance has become increasingly standardized, the terminology and definitions used in controlling and describing the quality of environmental data varies among geographical locations, regulatory agencies, accreditation bodies, and practitioners. For the purpose of the monitoring conducted under the Koocanusa Reservoir monitoring program, the terminology and processes relating to data quality are defined below.

Quality Assurance (QA) is a set of operating principles that, if strictly followed, will produce data with a quality that is defined and satisfies the intended use of the data. Included in QA is quality control (QC). Quality control involves special actions taken to measure and control data errors and variability associated with sampling, analysis, and reporting such that the resulting data are sufficiently accurate and precise to serve the purpose(s) for which they are collected. Ideally, performance elements will be controlled such that the variability observed in the data can be assumed to reflect real spatial or temporal variability. Quality control in an environmental monitoring program typically includes such elements as laboratory MDLs for chemical analyses, as well as requirements for collection and analysis of field and laboratory replicate samples,

field and laboratory blank sample analysis, laboratory recovery of known chemical additions to samples (spike recoveries), and analysis of standard reference materials, etc. (described below).

Data quality objectives (DQOs) represent the performance expectations for QC elements and serve as criteria for data acceptability. DQOs should be developed for new projects in advance of sample collection and analysis, and the performance expectations should be established based on consideration of how the data will be used (i.e., what questions will the data be used to answer) as well as the technical feasibility of collecting data of such quality. Guidance for establishing DQOs has been developed by the USEPA (2006).

Data quality assessment (DQA) is the process of comparing actual field and laboratory performance to the DQOs to determine the overall quality of the data. The goal of data quality assessment is to identify significant issues with the data (e.g., performance outside of accepted boundaries) and to take action in a timely and efficient manner to address errors and concerns. This process will help confirm that the data are associated with a defined level of quality and thus enhance the defensibility of the data in the context of their ultimate use.

Assurance of adequate data quality is possible only when specific data uses and DQOs have been defined. Analytical DQOs may pertain to factors such as sensitivity, precision, accuracy, comparability, compatibility, representativeness, and completeness.

QC samples are collected in the field and in the laboratory. General guidelines for the type of QC samples required to track and minimize the effects of bias and imprecision in the sampling effort are outlined below. The number of QC samples should correspond to a minimum of 10% of the total number of samples taken in the sampling period the QC samples are intended to represent. QC samples are integral to a QA program, and recommendations for their use should be strictly adhered to.

The quality assurance plan for the Koocanusa Reservoir monitoring plan includes a number of formal components and procedures, explained below, that will be used to assure the quality and integrity of data.

4.4.1.2 QC Indicators

Sensitivity describes the lowest concentration, or increment of concentration, that a laboratory technique is able to detect or quantitate with a certain level of confidence, which can be defined in different ways (e.g., see below). This limit must be less than the environmental quality guidelines to which the data will be compared and preferably 1/10th that value or lower since analytical precision is reduced at concentrations approaching the method detection limit (McQuaker 1999).

- **Laboratory reporting limit (LRL)**: The lowest concentration of an analyte reported within a reasonable degree of accuracy and precision, ideally synonymous with the lower limit of quantitation (LLOQ). The LRL is typically 3-10 times the method detection limit (MDL), but some guidelines are so low that the LRL is equal to the MDL in order to report to the guideline.
- **Lower Limit of Quantitation (LLOQ)** is the lowest concentration of an analyte that can be reliably measured within specified limits of precision and accuracy during routine operating conditions, as opposed to being detected which, in most cases, is the lowest concentration on the calibration curve.
- **Method detection limit (MDL)** usually refers to the minimum concentration of an analyte that can be measured and reported with 99% confidence to be greater than zero for a given matrix and specific method.

Precision refers to the degree of agreement between or among repeated measurements of the same characteristic. It may be determined by calculating the relative percent difference (for duplicate values) or relative standard deviation (for replicates of more than two), for field or laboratory samples.

Accuracy refers to how closely a result corresponds with the true or expected value and is often determined by comparing the value measured in a standard or reference sample to the certified (actual) value. QC analyses used to measure accuracy include standard recoveries, laboratory control samples, spiked blank samples, and spiked environmental samples.

Bias refers to the degree to which there is a systematic error in one direction from a true value (% Bias = % Recovery – 100 or % Bias = $(C - C_{standard})/C_{standard}$). Bias is not required to be assessed within the RAEMP if targets for data accuracy are being met for analytes of interest. However, bias should be evaluated if accuracy targets are not met and/or a pattern of potential bias is noted during the review of accuracy data.

4.4.1.3 QC Sample Types

Blanks are samples of de-ionized water and/or appropriate reagent(s) that are handled and analyzed by an analytical laboratory the same way as environmental samples. Blank samples will reflect contamination occurring in the field (in the case of field or trip blanks) or the laboratory (in the case of laboratory or method blanks). Blank samples are expected to have no quantifiable amount of target analytes present. However, concentrations up to twice the LRL are acceptable in recognition that reported concentrations in that range are associated with greater uncertainty, and provided the LRL is well below the benchmark or guideline to which sample data will be compared.

Certified reference materials are samples containing known chemical concentrations that are processed and analyzed by an analytical laboratory along with batches of environmental samples. The sample results are then compared to the known (e.g., certified) amount to provide a measure of analytical accuracy. The results are reported as the percent of the known amount that was recovered in the analysis.

Field blanks include samples submitted to the analytical laboratory from the field that are identified as a blank. These can include trip blanks, rinsates, equipment blanks, etc. so the type of field blank must be clearly specified by field personnel.

Field replicates (typically duplicates) are useful in documenting the precision of the sampling process. Field replicates are used to assess reproducibility of sample collection, preparation, and analysis, and heterogeneity of the matrix. Field replicates can include co-located samples and split samples taken in the field.

- **Co-located samples** are the type of field duplicate where independent samples are collected as close as possible to the same point in space and time. They are two separate samples taken from the same source, stored in separate containers, and analyzed independently by the same method and laboratory. These samples reflect imprecision of the sampling process as well as laboratory.
- **Field split samples** are a type of field duplicate where the sample is homogenized and then divided into two or more aliquots so that variability can be evaluated, (i.e., often between laboratories or methods). Homogenization may have an impact on sample integrity for some sample types (e.g., volatile organic carbons) and in these cases co-located samples may be more appropriate.

Internal (or QC) standards may be spiked into prepared field samples and QC samples (or sample extracts) by the laboratory for calibration and controlling the precision and bias of the applied analytical method. Their recovery is generally used to account for matrix effects and/or variability in instrument response by normalizing the response of the target analytes and surrogates.

Laboratory replicate samples (typically duplicates) are sub-samples taken by the laboratory from the same sample container and prepared and analyzed in the same way. The results from replicate analyses are used to evaluate analytical or measurement precision.

Matrix spikes are aliquots of environmental samples to which known concentrations of certain target analytes have been added by the laboratory before sample preparation and determinative procedures have been implemented. The matrix spike analysis is used to assess the potential

effects of matrix interferences on the accuracy (and potentially also bias) of the method by measuring the percent recovery of the known spike amount.

Method blanks are prepared and analyzed by the laboratory to assess background interference or contamination that exists in the analytical system that might lead to the reporting of elevated concentration levels or false positive data. The method blank is an analyte-free sample to which reagents are added in the same volumes or proportions as used in sample preparation and carried through the complete sample preparation, cleanup, and determinative procedures. The method blank results should be below the LLOQ for the target analytes being tested.

Organism sub-sampling accuracy refers to how closely the total sample abundance estimated by a laboratory based on counting organisms in a sub-sample (e.g., benthic invertebrates) reflects the total number of organisms actually present in the sample. To do this, the laboratory typically analyses a subset of samples in their entirety, while in the process also keeping track of organism counts for all sub-samples comprising the total sample. Then the % error is calculated for each subsample as:

> (([estimated total sample abundance based on processing of subsample] – [estimated total sample abundance based on processing of entire sample]) / (estimated total sample abundance based on processing of entire sample)) X 100.

If a sample is so large that it would be excessively time consuming to process the entire sample, then the same calculation is performed relative to the total sample abundance estimated from multiple sub-sample counts.

Organism sub-sampling precision refers the degree of agreement between sub-sample organism counts in laboratory processing of biological community samples (e.g., benthic invertebrates, plankton). The % error is calculated by computing the relative percent difference for pairs of sub-samples, as follows:

> ([organism abundance in sub-sample A]-[organisms abundance in sub-sample B] / [mean subsample abundance]) x 100

The CABIN laboratory sample processing protocol stipulates that sufficient sub-samples must be collected to total at least 300 organisms (Environment Canada 2012b). For both phytoplankton, zooplankton community samples, and fish aging (otoliths) sub-sampling accuracy will be assessed by performing replicate counts on 10% of samples (in this case, one sample each year). Replicate samples will be chosen at random and processed at different times from the original sample to reduce bias.

Organism recovery (or sorting recovery or efficiency) refers to laboratory processing of biological community samples (typically benthic invertebrates) to determine if organisms were

missed in the original processing of the sample. Typically, this involves a second analyst spot-checking the leftover sample debris after the first analyst has completed extraction of organisms.

4.4.2 Field QA/QC

Data quality begins with use of appropriate sampling equipment and instruments, adherence to SOPs for taking measurements or samples in the field, and appropriate and accurate documentation of relevant field information and observations.

Field instruments must be regularly calibrated, maintained, and operated in accordance with the manufacturer's instructions. Containers used for samples for chemical analyses should be kept closed, in a clean environment, away from dust, dirt, and fumes. Chemistry samples should never be permitted to get warm (and in the case of water or sediment samples should not freeze) and must be shipped to the laboratory promptly to meet holding time limits. Field sheets should be prepared in advance of the program and include prompts for documentation of the sampling location (GPS coordinates), relevant field conditions/measurements, samples taken, extra QC samples collected, and photographs taken. Field sheets must be signed and dated.

Chain-of-custody (COC) forms must also be filled out to achieve traceability of samples from the field to the laboratory.

4.4.3 Laboratory Data QA-QC

DQOs for have been established for different QC indicators applicable to the RAEMP (Table 4.1).

Chemical analysis of samples should be performed by a laboratory that has achieved accreditation for the relevant analyses through the Canadian Analytical Laboratory Association (CALA). Potential exceptions may include highly specialized, non-routine analyses for which formal certification is not currently available; however, in such cases, the QA/QC practices that will be followed and reported by the laboratory must be established in advance and conform to the general data quality control requirements established for the Koocanusa Reservoir monitoring program, as outlined in the next section.

In addition to the QA/QC requirements specified above, the following requirements will apply:

- Laboratories will be instructed to retain samples until data are reported and the quality of data is assessed relative to DQOs listed in Table 4.1
- Field sheets, sorted invertebrate samples, and fish age structures must be archived at least until the study report has been completed and undergone external technical review.

Table 4.1: Data Quality Objectives for Aquatic Ecological Samples

Quality Control Measure	Quality Control Sample Type/Check	Study Component					
		Water Quality	Sediment Quality	Tissue Quality	Plankton Community	Benthic Invertebrate Community	Fish Morphometrics
Analytical Laboratory Reporting Limits (LRL)	Comparison actual LRL versus target LRL	LRL for each parameter should be at least as low as applicable guidelines, ideally ≤1/10th guideline value[a]	LRL for each parameter should be at least as low as applicable guidelines, ideally ≤1/10th guideline value[a]	LRL for each parameter should be at least as low as applicable guidelines, ideally ≤1/10th guideline value[a]	n/a	n/a	n/a
Blank Analysis	Field Blank	<LRL[c]	n/a	n/a	n/a	n/a	n/a
	Field or Laboratory Blank	<LRL	n/a	n/a	n/a	n/a	n/a
Laboratory Precision	Laboratory Replicates	≤25% RPD or RSD	≤35% RPD or RSD[b]	≤30% RPD or RSD[b]	n/a	n/a	n/a
	Organism Sub-Sampling Precision	n/a	n/a	n/a	n/a	≤20% difference between sub-samples; minimum of 5% of each sample must be analyzed	n/a
Accuracy	Recovery of Blank Spike	80-120%	75-125%	75-125%	n/a	n/a	n/a
	Recovery Matrix Spike	75-125%	75-125%	75-125%	n/a	n/a	n/a
	Recovery of Certified Reference Material, QC Standards	85-115%	70-130%	70-130%	n/a	n/a	n/a
	Organism Recovery	n/a	n/a	n/a	n/a	minimum 90% recovery	n/a
	Organism Sub-Sampling Accuracy	n/a	n/a	n/a	replicate counts on 10% of samples	80-120%	n/a
	Instrument Accuracy	n/a	n/a	n/a	n/a	n/a	use instruments that provide measurement accuracy of ≤10% for weight (whole organism or tissue) and length

[a] or below predictions, if applicable and no guideline exists for the substance.

[b] RPD - Relative Percent Difference in the case of duplicate samples; RSD - Relative Standard Deviation in the case of more than two replicate samples

[c] concentrations up to two-times the laboratory LRL are acceptable if the reported value is still less than applicable guideline or benchmark

n/a - not applicable.

4.5 Data Quality Assessment, Data Management Responses, and Reporting

The overall objective of a quality assurance program is to control errors to the degree possible to maximize their quality, usefulness, and reliability. Data quality assessment (DQA) involves the process of evaluating how well DQOs and other QC requirements were met. The DQA will be performed before the data are analyzed and interpreted relative to the study objectives. The assessment will be based on a direct comparison of QC sample results with the objectives specified in Table 4.1 for each sample type. Relevant data will be presented in the final interpretive project report. Observations that may affect the reliability of the collected data with respect to serving the project objectives must be clearly identified.

5 REPORTING AND SCHEDULE

5.1 Reporting

The data collected during the 2018 to 2020 Koocanusa Reservoir monitoring program will be reported on an annual basis, by June 30th the following year. The reports will provide an overview of the sampling completed during the year, and present the results of the data collected in accordance with Section 10.8 of Permit 107517. Annual reports will be specific to the data collected in support of this study design. Alterations or additions to subsequent sample periods will be discussed with the EMC prior to the next years sampling events. In 2020, the data collected from the first two years of this program (i.e., 2018 and 2019) will be integrated into the RAEMP report, which will be due prior to completion of field activities in 2020.

5.2 Schedule

Data compilation and analysis will be initiated upon receipt of data from field sampling programs. As 2018 is the initial year of the 2018 to 2020 sampling program, a data package will be prepared prior to the first EMC meeting in 2019. It is anticipated that the EMC will provide input before submission of the annual report by June 30, 2019, as per Section 10.8 of Permit 107517. Subsequent field sampling programs (beginning in April 2019 through to 2020) will again be followed by data packages and the submission of annual reports at the end of June in 2020 and 2021. Data collected until the end of 2019 will be included within the next RAEMP report.

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APPENDIX A
SURFACE WATER MONITORING PLAN

Koocanusa Reservoir Water Quality Monitoring Plan

2018

Teck

1.0 Objectives

Surface water quality data within Koocanusa Reservoir, British Columbia (BC) are being collected to better characterize water quality and understand spatial, and temporal (seasonal and annual) variability. Data collected over time in a consistent manner will allow for trend monitoring in water quality including the effectiveness of Teck's mitigation actions associated with implementation of the Elk Valley Water Quality Plan (EVWQP) and Permit 107517.

Objectives associated with this program include:

1. Monitor overall water quality in Koocanusa Reservoir, BC to meet Permit 107517 sampling requirements at permitted locations. Data is compared to permit limits, BC water quality guidelines, targets established within the EVWQP and reference conditions.

2. Inform management decisions and support other monitoring programs at a regional scale (e.g., Regional Aquatic Effects Monitoring Program [RAEMP], Koocanusa Reservoir Monitoring Program).

In addition to the above-listed objectives, the sampling program considers active monitoring programs conducted outside of the Designated Area (e.g., Montana Department of Environmental Quality), and to the extent possible, ensures that sampling methods and analytical procedures are harmonized to facilitate direct data comparisons.

2.0 Sample Locations, Frequency and Timing

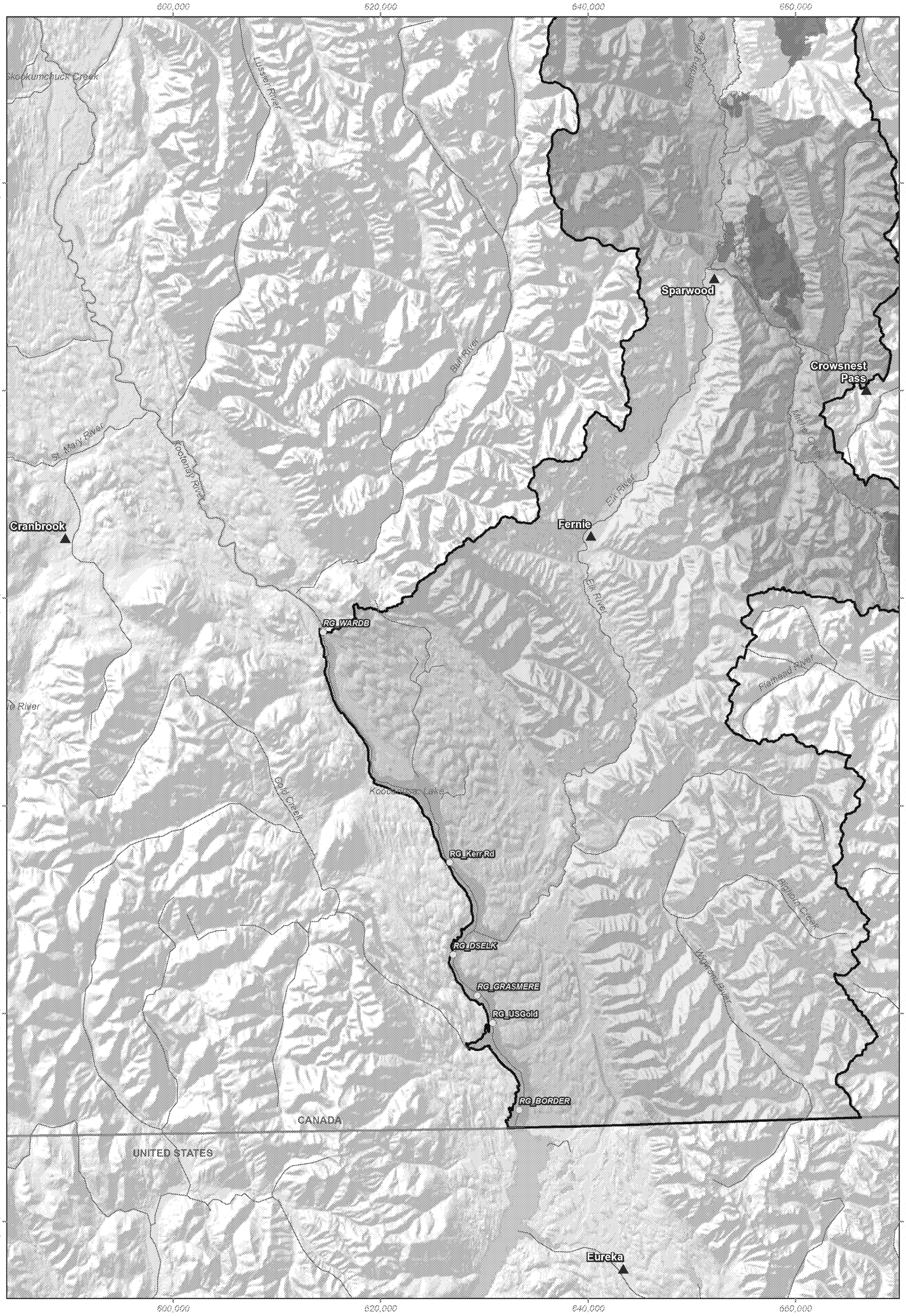
Water levels within the reservoir experience significant annual fluctuations which are controlled by two primary factors: 1) spring inflow volumes via the Kootenay, Bull and Elk Rivers; and 2) annual drawdown (Hardy and Paragamian 2013, Richards 1997, Crozier and Nordin 1983). Management objectives of the reservoir include flood and environmental protection, hydropower, and recreation. Using an area/capacity curve, HydroQual (1990) illustrated that the Canadian portion of the reservoir experiences the greatest relative change in water elevation. For instance, at full pool, water depth at the Canada-US border is approximately 40 meters (m), but during annual drawdown is ≤10 m. Associated variability in conditions was considered in the development of the monitoring program.

The sampling locations for the Koocanusa Reservoir water quality sites are listed in Table 1 and illustrated in Figure 1. The sampling locations contained in Table 1 are, in some cases, approximate locations and some "field fitting" may be required to ensure safe access during sampling (e.g. ice coverage or riverine conditions).

Table 1. Water Quality Monitoring Stations in Koocanusa Reservoir

Station Name / Descriptor	Station Code	EMS #	Universal Transverse Mercator Coordinates	
			Easting	Northing
Koocanusa Reservoir at Wardner	RG_WARDB	N/A	614501	5476717
Koocanusa Reservoir u/s Elk River and d/s of Kikkoman Creek	RG_KERRRD	E300095	626575	5454366
Koocanusa Reservoir d/s Elk River	RG_DSELK	E300230	627055	5445568
Koocanusa Reservoir West of Grasmere	RG_GRASMERE	E300092	629326	5441735
Koocanusa Reservoir u/s Gold Creek	RG_USGOLD	E300093	630811	5439055
Koocanusa Reservoir u/s Canada/US Border	RG_BORDER	E300094	633382	5430699

Water Quality Monitoring Stations in Lake Koocanusa



N

0 2.5 5 10 Kilometers

1:332,000

- Communities
- Water Quality Monitoring Stations
- Rivers
- Teck Coal Mine Operations
- Ministerial Order Boundary

EVWQP MU

- MU-1
- MU-2
- MU-3
- MU-4
- MU-5
- MU-6

Teck

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Sampling frequency will be weekly from April 1st to July 15th and otherwise monthly as field conditions permit. Timing of monthly sampling will, to the extent possible, be consistent with regional surface water sampling efforts conducted by Teck Coal Limited (Teck) operations. It is acknowledged *a priori* that there will be periods of time (e.g., winter) in which safety issues and concerns (e.g., thin ice, and/or ice cover with falling/rapidly fluctuating water levels) may preclude surface water sampling activities on the reservoir. Weekly sampling should be conducted during the ascending limbs of the hydrograph and full pool when the reservoir has the greatest potential to be thermally stratified (May 1 – July 15) (Figure 2). The descending limbs of the hydrograph typically occur during winter months when sampling is limited due to ice, combined with dropping water levels, restricting access on the reservoir.

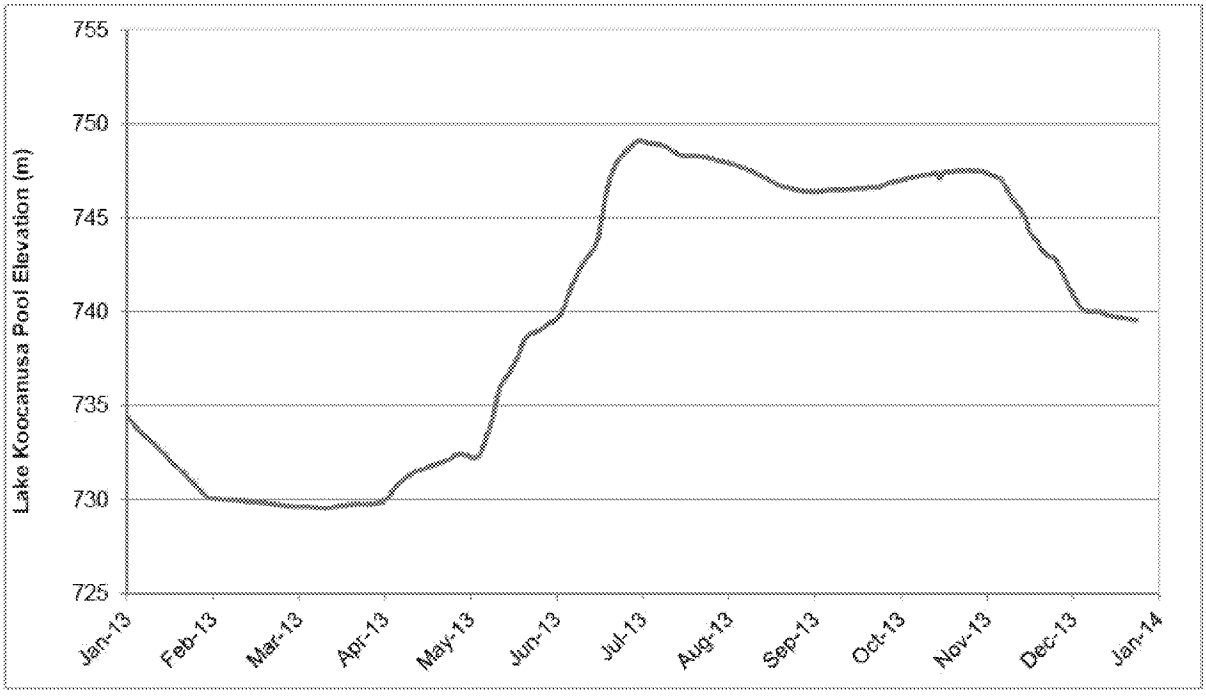

Figure 2: Typical annual elevation fluctuations observed in Koocanusa Reservoir
Data from United States Army Corps of Engineers, 2014

3.0 Reservoir Sampling Methods and Monitoring Parameters

Water sampling activities will be completed in accordance with methods outlined by the 2013 edition of the British Columbia Field Sampling Manual (Clark, M.J.R. (editor). 2003), Teck's field monitoring manual (Exponent, 2012) and consistent with the Montana Department of Environmental Quality "*Lake Koocanusa Sampling Project – 2013: Water Quality Sampling Plan*".

Prior to sampling, the crew will first determine whether or not the water column is stratified by lowering a data logger or multimeter probe set to log depth, and temperature. Stratification into an epilimnion and hypolimnion will be confirmed wherever a thermocline (defined as a 1°C change over 1 meter depth) is recorded. This temperature differential must be sustained in order to constitute stratification. Sampling will be conducted as per the sample decision tree shown in Figure 3. Where stratified, one composite sample will be formed from three evenly spaced grab samples in the epilimnion (samples identified as S1) and one composite sample similarly from the hypolimnion (samples identified as S2). Where unstratified, samples will be collected 3 m from the

surface (samples identified as U1), 3 m from the substrate (samples identified as U3) and at the mid-point of the water column (samples identified as U2). Samples will be collected with a Van Dorn sampler or equivalent depth sampler and labelled as above. Note that in certain conditions when the reservoir level is very low, conditions are essentially riverine. In these conditions it may only be possible to obtain a single sample, collected from the shoreline, at the closest safe location to the permitted sample location. Safety of a location will be assessed with respect to reservoir bank stability, ground consistency (i.e. ice shelves and mud flats), flow characteristics, etc. Efforts will be taken to conduct shore samples matching the permitted sample location's latitude however due to access issues the sampling location may be adjusted downstream to a safe alternative as close to the permitted sampling location as possible.

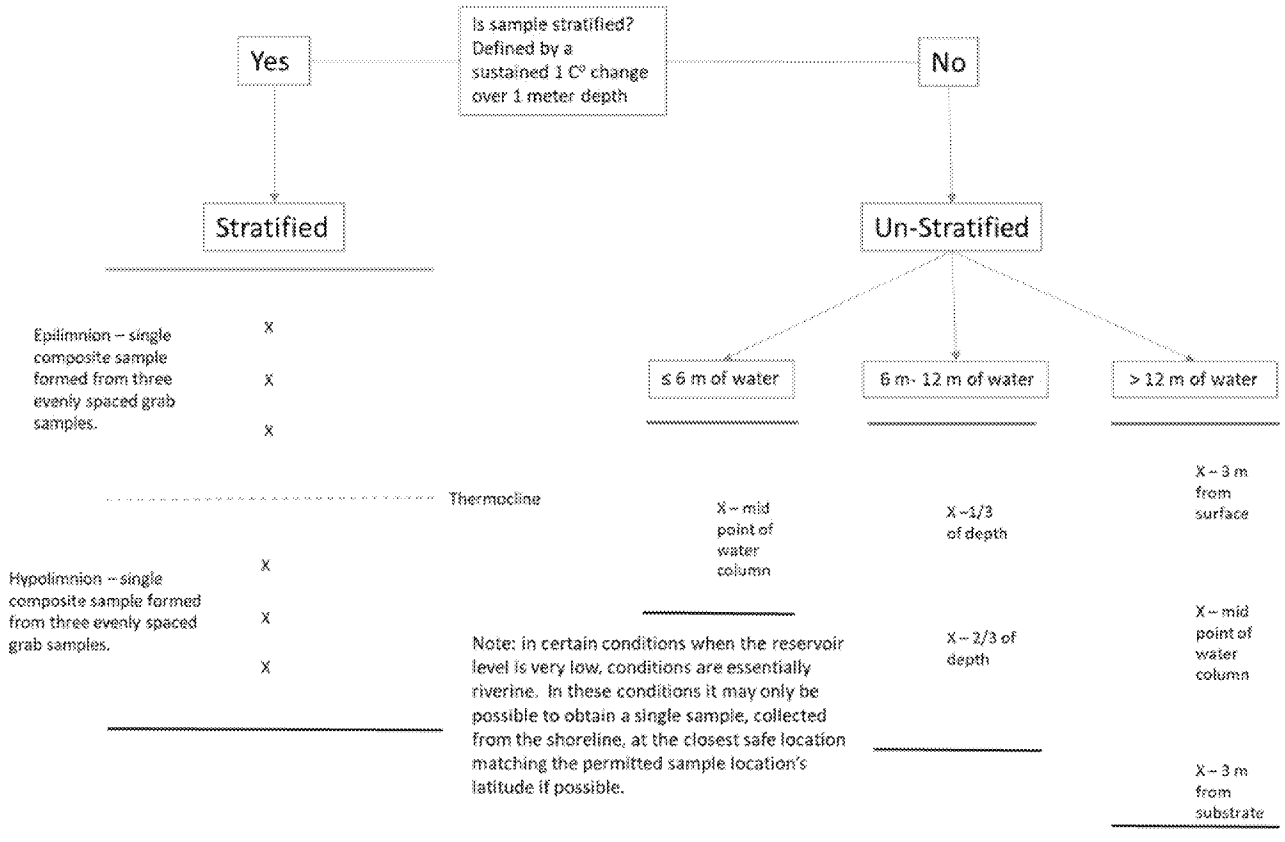

Figure 3: Sampling decision tree for depth integrated sampling in Koocanusa Reservoir

Field Measurements

Upon arrival at a monitoring location (Table 1), general water quality parameters (i.e., water temperature, pH, dissolved oxygen, specific conductivity, and oxidative-reduction potential) will be measured *in situ* at all sampling locations using an YSI 650/6600 multi-probe sensor or equivalent. The meter(s) will be calibrated daily before the start of work. A vertical profile of dissolved oxygen and temperature will be conducted monthly.

A secchi disc depth measurement will also be collected at each monitoring site. The disk will be lowered until it is no longer visible and the depth recorded. The disk is then raised and the depth at which it reappears is recorded. Observations are made on the shaded side of the boat by a person not wearing polarized glasses. During riverine conditions it may only be possible to obtain a single sample, collected from the shoreline, at the closest safe location to matching the permitted sample location. During these conditions a secchi disk measurement may not be feasible due to the depth

and safety of a location. The safety of a location will be assessed with respects to reservoir bank stability, ground consistency (i.e. ice shelves), flow characteristics, etc.

Analytical Measurements

Samples will be collected in sample bottles provided by the laboratory and preserved, as appropriate, for the analyses detailed in Table 25 of the Permit 107517 as show below:

Table 25- Surface Water Monitoring Program: Explanatory Notes

a	**Field Parameters** must include water temperature, specific conductance, dissolved oxygen, pH; for Koocanusa Reservoir locations this includes vertical profiles of dissolved oxygen and temperature
b	**Conventional Parameters** must include specific conductance, total dissolved solids, total suspended solids, hardness, alkalinity, dissolved organic carbon, total organic carbon, turbidity.
c	**Major Ions** must include bromide, fluoride, calcium, chloride, magnesium, potassium, sodium, sulphate.
d	**Nutrients** must include ammonia, nitrate, nitrite, TKN, orthophosphate, total phosphorus.
e	**Dissolved Metals Scan** must include aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, tin, titanium, uranium, vanadium, and zinc. **Total Metals Scan** must include aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, tin, titanium, uranium, vanadium, and zinc.

For chlorophyll-a, a fixed volume of sample water is filtered in the field, with the filter supplied to the laboratory in a lab-supplied sample tube.

Analysis will be conducted in accordance with the procedures described in the most recent edition of the British Columbia Laboratory Methods Manual for the Analysis of Water, Wastewater, Sediment, Biological Materials and Discrete Ambient Air by third party certified laboratory

4.0 Quality Assurance and Quality Control Requirements

Quality Assurance and Quality Control (QA/QC) procedures for monitoring will consist of calibrating field meters and collecting necessary field QC samples per requirements detailed in Clark (2003), Teck's field monitoring manual (Exponent, 2012) and the BC Field Sampling Manual (2013). Specific QA/QC measures to be followed are presented below.

Field quality control (QC) samples will be used to assess sample variability and evaluate potential sources of contamination. Field QC samples will include field replicates, blanks and equipment rinsate blanks. The following QC samples will be collected in the field and analyzed by the analytical laboratory.

Field Calibration - Field measurements will be collected during each surface water sampling event and at each monitoring location. Meter(s) used to obtain field measurements will be calibrated daily before the start of work. Calibration will be in accordance with procedures and schedules outlined in the particular instrument's operations and maintenance manual. If calibration fails, a second attempt will be made to calibrate the unit. If the second attempt fails, the unit will be replaced with a backup.

Field Replicate Samples (i.e. field duplicate) - Blind field replicate samples will be collected and analyzed to assess the environmental, sample processing, and laboratory variability within a sampling location. Field replicates will be collected in the same manner as the original field sample and will be assigned a unique sample number so that the laboratory will not know it is a QC

sample. Field replicates will be collected at the same water depth and same location as the parent sample and at a minimum frequency of 10 percent of total samples taken.

Field Blank Samples – These should be provided using laboratory supplied de-ionized water and should be exposed to all the same potential sources of contamination as other samples, including handling, filtration and preservation. Field blanks will be prepared at the same location as the "parent" sample and should be provided at a minimum frequency of 1 per sampling event.

Trip (travel) Blanks – These are pre-filled, laboratory prepared samples that are carried through the sample collection event but remain unopened. These will be conducted at a minimum frequency of 1 per sampling event.

Equipment Rinsate Blanks - Equipment rinsate blanks will be collected to help identify possible contamination from the sampling environment or from the sampling equipment (e.g., Van Dorn sampler). One equipment rinsate blank will be generated for each sampling event. Equipment rinsate blanks will consist of running distilled/deionized water through the sampling equipment after decontamination.

5.0 Sample Handling and Records

Sample coolers and packing materials will be supplied by the analytical laboratory. Samples will be packed in a cooler with each set of sample bottle place into a large plastic bag. Glass jars (if used) will be packed to prevent breakage and separated in the cooler by bubble wrap or other shock-absorbent material. Ice in sealed plastic bags or ice packs will be placed in the cooler to maintain a temperature of approximately 4°C (±2°C). When the cooler is full the chain-of-custody (COC) form will be placed into a zip-locked bag and placed in the cooler.

Field data collection forms, digital photos, and COC's will be appropriately documented and stored per Teck's field monitoring manual (Exponent, 2012). Laboratory results will be provided to Teck in Electronic Data Deliverable format consistent with Teck's EQuIS database management procedures. Field Results will be provided to Teck in Electronic Data Deliverable format consistent with Teck's Regional sampling nomenclature guide. Data will be uploaded by Teck to the ENV Environmental Monitoring System database as per Teck's BC ENV EMS Upload Report - User Guide.

6.0 Data Analysis

Data collected under this plan will be reported on as part of Teck's Permit 107517 quarterly and annual water quality reports. This data will also be analyzed and reported on within the Regional Aquatic Effects Monitoring Program and Koocanusa Reservoir Monitoring Program.

7.0 Safety and Limiting Factors

There are several safety concerns and limiting factors that could affect the sampling program. Sampling teams need to be aware of weather conditions, including potential sudden changes in weather, ice, floating and submerged debris. Personal floatation devices (PFDs) are mandatory for all members of field crews while working on or adjacent to water. Sampling teams must have a minimum of two people who work within sight/sound of one another to avoid any inherent risks of working alone. If conditions are deemed unsafe by the sampling team, the attempt to collect the

sample will be documented and sampling will be delayed until such time that conditions are determined safe. Results of the sampling events or attempts of the events will be summarized in the Permit 107517 quarterly reports.

8.0 Linkage with Regional Aquatic Effects Monitoring Program

All data and evaluation completed as part of this water quality sampling plan will be used to inform and evaluate chemical conditions within the reservoir completed as part of the ongoing Koocanusa Reservoir Monitoring Program. Future updates to the study design for Koocanusa Reservoir will incorporate both the biological and the water quality sampling plan. The Koocanusa Reservoir Monitoring Program has been developed as a supporting study to the RAEMP study design based on differences in aquatic habitat, receptors, and stressors (e.g., management of water levels in the reservoir), but results from the former will be incorporated in the RAEMP reporting as per Permit 107517 requirements.

9.0 References

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APPENDIX B
A PRIORI POWER ANALYSIS

APPENDIX B *A PRIORI* POWER ANALYSIS

B1 DATA ANALYSIS

An *a priori* power analysis was conducted for peamouth chub and redside shiner separately for each sex and downstream area (Elk River and Gold Creek) to estimate the sample sizes required to detect various effect sizes relative to the upstream area (Sand Creek) (Appendix Table B.1 and B.2). For endpoints analyzed by ANCOVA, an estimate of variability was obtained as the square root of the mean square error term in the ANOVA model (i.e., the pooled standard deviation of the regression residuals) for the downstream and upstream area data analyzed separately by year. A pooled estimate of variability was generated among years (2014, 2015, and 2016) for peamouth chub and a single estimate of variability was obtained for redside shiner from the 2016 sampling. The measure of variability for each year was based on the interaction ANCOVA model when the interaction between area and the covariate was significant ($\alpha = 0.05$) and it was based on the parallel slope ANCOVA model when the interaction between area and the covariate was not significant. For endpoints analyzed using the two-sample t-test with no data transformation, the measure of variability was the coefficient of variation, defined as the pooled standard deviation between areas (upstream and downstream) divided by the mean of the area upstream of the Elk River. The data for t-tests were $\log_{10}$-transformed when required to meet the assumptions of normality and homogeneity of variances, and power analyses were based on the pooled standard deviation of residuals. The standard deviation for female Sand Creek redside shiner was 0 (all age 3) so the standard deviation for the downstream area fish was used as the estimate of variability for the age endpoint. If the assumptions of normality and homogeneity of variances were not met for a t-test (tested using Shapiro Wilks' test and Levene's test at $\alpha = 0.05$, respectively) then the sample sizes required to detect various effect sizes were estimated for the Mann-Whitney test, by multiplying sample sizes for a two-sample t-test by 0.864. The value of 0.864 is the lower bound of the asymptotic relative efficiency of the Mann-Whitney test and the two-sample t-test (Hodges and Lehmann 1956) and provides a conservative estimate of the power of the Mann-Whitney test. All sample size estimates were conducted using the two-sample t-test power calculator in Minitab 17 Statistical Software (2010) using $\alpha = \beta = 0.1$.

Table B.1: Estimates of Sample Sizes Required to Detect Various Effect Sizes for Peamouth Chub Health Endpoints For Downstream Areas (Elk River and Gold Creek) Relative to the Upstream Sand Creek Area, based on Estimates of Variability from 2014, 2015, and 2016

Site	Sex	Endpoint	Variables		Model	S[a]	COV (%)[b]	Minimum Sample Size to Detect an Effect Size (% Increase/Decrease Relative to Reference) with α=β=0.1								
			Response	Covariate				log(Response)	5%	10%	20%	25%	30%	33%	40%	50%	100%
									-5%	-9%	-17%	-20%	-23%	-25%	-29%	-33%	-50%
								Response	±5%	±10%	±20%	±25%	±30%	±33%	±40%	±50%	±100%
Elk River	Female	Length-at-age	log[Fork Length (cm)]	Age	ANCOVA	0.0215	-	log(Response)	19	6	3	3	2	2	2	2	2
		Weight-at-age	log[Adjusted Body Weight (g)]	Age	ANCOVA	0.0543	-	log(Response)	114	31	9	7	5	5	4	3	2
		Relative Gonad Weight	log[Gonad Weight (g)]	log[Adjusted Body Weight (g)]	ANCOVA	0.1021	-	log(Response)	399	105	30	20	15	13	10	7	3
		Relative Liver Weight	log[Liver Weight (g)]	log[Adjusted Body Weight (g)]	ANCOVA	0.0972	-	log(Response)	362	96	27	18	14	12	9	7	3
		Condition	log[Adjusted Body Weight (g)]	log[Fork Length (cm)]	ANCOVA	0.0329	-	log(Response)	42	12	4	3	3	3	3	2	2
		Body Length	log[Fork Length (cm)]	-	t-test	0.0333	-	log(Response)	43	12	4	4	3	3	3	2	2
		Body Weight	log[Adjusted Body Weight (g)]	-	t-test	0.0999	-	log(Response)	382	101	28	19	14	12	9	7	3
		Age	log[Age]	-	t-test	0.1617	-	log(Response)	999	263	73	49	36	30	22	16	6
	Male	Length-at-age	log[Fork Length (cm)]	Age	ANCOVA	0.0281	-	log(Response)	31	9	4	3	3	3	2	2	2
		Weight-at-age	log[Adjusted Body Weight (g)]	Age	ANCOVA	0.0836	-	log(Response)	268	71	20	14	10	9	7	5	3
		Relative Gonad Weight	log[Gonad Weight (g)]	log[Adjusted Body Weight (g)]	ANCOVA	0.1416	-	log(Response)	766	202	56	38	28	23	17	12	5
		Relative Liver Weight	log[Liver Weight (g)]	log[Adjusted Body Weight (g)]	ANCOVA	0.0793	-	log(Response)	241	64	18	13	10	8	6	5	3
		Condition	log[Adjusted Body Weight (g)]	log[Fork Length (cm)]	ANCOVA	0.0285	-	log(Response)	32	9	4	3	3	3	2	2	2
		Body Length	Fork Length (cm)	-	t-test	-	10.42	Response	76	20	6	4	4	3	3	3	2
		Body Weight	Adjusted Body Weight (g)	-	t-test	-	29.35	Response	591	149	38	25	18	15	10	7	3
		Age	Age	-	t-test	-	40.09	Response	1,102	276	70	45	32	26	18	12	4
Gold Creek	Female	Length-at-age	log[Fork Length (cm)]	Age	ANCOVA	0.0220	-	log(Response)	20	6	3	3	2	2	2	2	2
		Weight-at-age	log[Adjusted Body Weight (g)]	Age	ANCOVA	0.0629	-	log(Response)	152	41	12	8	7	6	5	4	3
		Relative Gonad Weight	log[Gonad Weight (g)]	log[Adjusted Body Weight (g)]	ANCOVA	0.1017	-	log(Response)	396	105	29	20	15	13	10	7	3
		Relative Liver Weight	log[Liver Weight (g)]	log[Adjusted Body Weight (g)]	ANCOVA	0.1036	-	log(Response)	411	108	31	21	15	13	10	7	4
		Condition	log[Adjusted Body Weight (g)]	log[Fork Length (cm)]	ANCOVA	0.0300	-	log(Response)	36	10	4	3	3	3	2	2	2
		Body Length	log[Fork Length (cm)]	-	t-test	0.0433	-	log(Response)	73	20	6	5	4	4	3	3	2
		Body Weight	log[Adjusted Body Weight (g)]	-	t-test	0.1235	-	log(Response)	583	154	43	29	21	18	13	10	4
		Age	log[Age]	-	t-test	0.1658	-	log(Response)	1,050	276	76	51	37	31	23	16	7
	Male	Length-at-age	log[Fork Length (cm)]	Age	ANCOVA	0.0267	-	log(Response)	28	8	3	3	3	3	2	2	2
		Weight-at-age	log[Adjusted Body Weight (g)]	Age	ANCOVA	0.0903	-	log(Response)	312	83	23	16	12	10	8	6	3
		Relative Gonad Weight	log[Gonad Weight (g)]	log[Adjusted Body Weight (g)]	ANCOVA	0.1567	-	log(Response)	938	247	68	46	34	28	21	15	6
		Relative Liver Weight	log[Liver Weight (g)]	log[Adjusted Body Weight (g)]	ANCOVA	0.1299	-	log(Response)	645	170	47	32	23	20	15	11	5
		Condition	log[Adjusted Body Weight (g)]	log[Fork Length (cm)]	ANCOVA	0.0308	-	log(Response)	37	11	4	3	3	3	3	2	2
		Body Length	Fork Length (cm)	-	t-test	-	7.99	Response	45	12	4	3	3	3	2	2	2
		Body Weight	Adjusted Body Weight (g)	-	t-test	-	23.31	Response	373	94	24	16	12	10	7	5	3
		Age	Age	-	t-test	-	30.73	Response	648	163	42	27	19	16	11	8	3

[a] Pooled standard deviation of the regression residuals.

[b] Coefficient of variation (pooled standard deviation/reference mean)×100%.

Table B.2: Estimates of Sample Sizes Required to Detect Various Effect Sizes for Redside Shiner Health Endpoints for Downstream Areas (Elk River and Gold Creek) Relative to the Upstream Area (Sand Creek), Based on Estimates of Variability from 2016

Area	Sex	Endpoint	Variables		Model	S[a]	COV (%)[b]	Minimum Sample Size to Detect an Effect Size (% Increase/Decrease Relative to Reference) with α=β=0.1									
			Response	Covariate				log(Response)	5%	10%	20%	25%	30%	33%	40%	50%	100%
									-5%	-9%	-17%	-20%	-23%	-25%	-29%	-33%	-50%
								Response	±5%	±10%	±20%	±25%	±30%	±33%	±40%	±50%	±100%
Elk River	Female	Length-at-age	log[Fork Length (cm)]	Age	ANCOVA	0.0238	-	log(Response)	23	7	3	3	3	2	2	2	2
		Weight-at-age	log[Adjusted Body Weight (g)]	Age	ANCOVA	0.0745	-	log(Response)	213	57	16	11	9	7	6	4	3
		Relative Gonad Weight	log[Gonad Weight (g)]	log[Adjusted Body Weight (g)]	ANCOVA	0.1212	-	log(Response)	562	148	41	28	21	17	13	9	4
		Relative Liver Weight	log[Liver Weight (g)]	log[Adjusted Body Weight (g)]	ANCOVA	0.1448	-	log(Response)	801	211	58	39	29	24	18	13	5
		Condition	log[Adjusted Body Weight (g)]	log[Fork Length (cm)]	ANCOVA	0.0285	-	log(Response)	32	9	4	3	3	3	2	2	2
		Body Length	log[Fork Length (cm)]	-	t-test	0.0235	-	log(Response)	22	7	3	3	2	2	2	2	2
		Body Weight	log[Adjusted Body Weight (g)]	-	t-test	0.0732	-	log(Response)	205	55	16	11	8	7	6	4	3
		Age	Age	-	M-W	-	12.10	Response	118	30	9	6	5	5	4	4	2
	Male	Length-at-age	log[Fork Length (cm)]	Age	ANCOVA	0.0242	-	log(Response)	24	7	3	3	3	2	2	2	2
		Weight-at-age	log[Adjusted Body Weight (g)]	Age	ANCOVA	0.0711	-	log(Response)	194	52	15	10	8	7	5	4	3
		Relative Gonad Weight	log[Gonad Weight (g)]	log[Adjusted Body Weight (g)]	ANCOVA	0.1604	-	log(Response)	983	258	71	48	35	29	22	15	6
		Relative Liver Weight	log[Liver Weight (g)]	log[Adjusted Body Weight (g)]	ANCOVA	0.1448	-	log(Response)	801	211	58	39	29	24	18	13	5
		Condition	log[Adjusted Body Weight (g)]	log[Fork Length (cm)]	ANCOVA	0.0319	-	log(Response)	40	11	4	3	3	3	3	2	2
		Body Length	log[Fork Length (cm)]	-	t-test	0.0263	-	log(Response)	28	8	3	3	3	3	2	2	2
		Body Weight	log[Adjusted Body Weight (g)]	-	t-test	0.0775	-	log(Response)	230	61	18	12	9	8	6	5	3
		Age	log[Age]	-	t-test	0.0911	-	log(Response)	318	84	24	16	12	10	8	6	3
Gold Creek	Female	Length-at-age	log[Fork Length (cm)]	Age	ANCOVA	0.0229	-	log(Response)	21	7	3	3	2	2	2	2	2
		Weight-at-age	log[Adjusted Body Weight (g)]	Age	ANCOVA	0.0714	-	log(Response)	196	52	15	11	8	7	5	4	3
		Relative Gonad Weight	log[Gonad Weight (g)]	log[Adjusted Body Weight (g)]	ANCOVA	0.1612	-	log(Response)	992	261	72	49	35	30	22	16	6
		Relative Liver Weight	log[Liver Weight (g)]	log[Adjusted Body Weight (g)]	ANCOVA	0.1673	-	log(Response)	1,069	281	78	52	38	32	24	17	7
		Condition	log[Adjusted Body Weight (g)]	log[Fork Length (cm)]	ANCOVA	0.0566	-	log(Response)	123	33	10	7	6	5	4	3	2
		Body Length	log[Fork Length (cm)]	-	t-test	0.0226	-	log(Response)	21	6	3	3	2	2	2	2	2
		Body Weight	log[Adjusted Body Weight (g)]	-	t-test	0.0716	-	log(Response)	197	52	15	11	8	7	5	4	3
		Age	Age	-	M-W	-	18.50	Response	273	69	19	13	9	8	6	5	2
	Male	Length-at-age	log[Fork Length (cm)]	Age	ANCOVA	0.0185	-	log(Response)	14	5	3	2	2	2	2	2	2
		Weight-at-age	log[Adjusted Body Weight (g)]	Age	ANCOVA	0.0583	-	log(Response)	131	35	11	7	6	5	4	3	2
		Relative Gonad Weight	log[Gonad Weight (g)]	log[Adjusted Body Weight (g)]	ANCOVA	0.1808	-	log(Response)	1,248	328	90	61	44	37	27	19	7
		Relative Liver Weight	log[Liver Weight (g)]	log[Adjusted Body Weight (g)]	ANCOVA	0.1301	-	log(Response)	647	170	47	32	24	20	15	11	5
		Condition	log[Adjusted Body Weight (g)]	log[Fork Length (cm)]	ANCOVA	0.0329	-	log(Response)	42	12	4	3	3	3	3	2	2
		Body Length	log[Fork Length (cm)]	-	t-test	0.0277	-	log(Response)	31	9	4	3	3	3	2	2	2
		Body Weight	log[Adjusted Body Weight (g)]	-	t-test	0.0828	-	log(Response)	263	70	20	14	10	9	7	5	3
		Age	log[Age]	-	t-test	0.0883	-	log(Response)	299	79	23	15	12	10	8	6	3

[a] Pooled standard deviation of the regression residuals.

[b] Coefficient of variation (pooled standard deviation/reference mean)×100%.